

AD-A193 232 VERTICAL DIRECTIONALITY OF AMBIENT NOISE AT 32 DEG N AS 1/2
A FUNCTION OF LONG. (U) SCIENCE INSTITUTION OFAD-A193 232 VERTICAL DIRECTIONALITY OF AMBIENT NOISE AT 32 DEG N AS 1/2
A FUNCTION OF LONG. (U) SCIENCE INSTITUTION OF

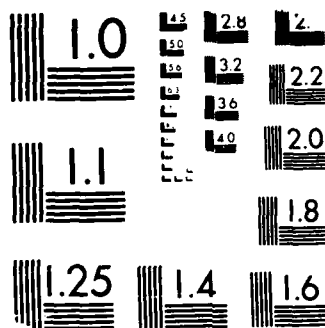
UNCLASSIFIED W S HODGKISS ET AL. JAN 88 MPL-TM-387-A

UNCLASSIFIED W S HODGKISS ET AL. JAN 88 MPL-TM-387-A

UNCLASSIFIED N S HODGKISS ET AL. JAN 88 MPL-TM-387-A F/G 20/1

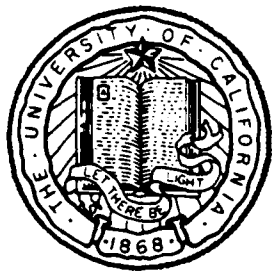
UNCLASSIFIED M S HODGKISS ET AL. JAN 88 MPL-TM-387-A F/G 20/1 NL

A 10x10 grid of squares, with the top-left square missing, forming a shape resembling a staircase or a corner.



MICROCOPY RESOLUTION TEST CHART

1010 ALI - JANUARY 1963 A



MARINE PHYSICAL
LABORATORY

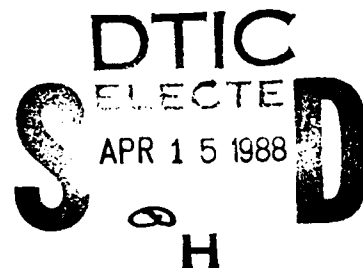
SCRIPPS INSTITUTION OF OCEANOGRAPHY

San Diego, California 92152

AD-A193 232

VERTICAL DIRECTIONALITY OF AMBIENT NOISE
AT 32° N AS A FUNCTION OF LONGITUDE

W. S. Hodgkiss and F. H. Fisher



MPL TECHNICAL MEMORANDUM 387-A

MPL-U-32/86

Approved for public release; distribution unlimited.

January 1988

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) MPL TECHNICAL MEMORANDUM 387-A [MPL-U-32/86]			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION Marine Physical Laboratory		6b. OFFICE SYMBOL (If applicable) MPL		7a. NAME OF MONITORING ORGANIZATION Office of Naval Research Department of the Navy	
6c. ADDRESS (City, State, and ZIP Code) University of California, San Diego Scripps Institution of Oceanography San Diego, CA 92152		7b. ADDRESS (City, State, and ZIP Code) 800 North Quincy Street Arlington, VA 22217-5000			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Office of Naval Research		8b. OFFICE SYMBOL (If applicable) ONR		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00014-84-K-0097 and N00014-87-C-0127	
8c. ADDRESS (City, State, and ZIP Code) Department of the Navy 800 North Quincy Street Arlington, VA 22217-5000		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) Vertical Directionality of Ambient Noise at 32°N as a Function of Longitude					
12. PERSONAL AUTHOR(S) W. S. Hodgkiss and F. H. Fisher					
13a. TYPE OF REPORT tech memo		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) January 1988	
15. PAGE COUNT 127					
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) ambient noise, vertical arrays, vertical distribution		
FIELD	GROUP	SUB-GROUP			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Measurements have been made of the ambient noise field between 25 and 300 Hz with vertical arrays at 32°N (124°W, 136°W, and 150°W). Substantial differences in the vertical distribution of noise have been measured, especially at the higher frequencies which can be interpreted in the context of attenuation by seawater sound absorption of coastal shipping. Due to substantial differences in weather at the stations, these measurements also provide an opportunity to observe the effect of weather on the vertical distribution of ambient noise.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL W. S. Hodgkiss			22b. TELEPHONE (Include Area Code) 619-534-1798		22c. OFFICE SYMBOL MPL

**Vertical Directionality of Ambient Noise
at 32 ° N as a Function of Longitude**

W.S. Hodgkiss and F.H. Fisher

Marine Physical Laboratory
Scripps Institution of Oceanography
San Diego, CA 92152

Abstract

Measurements have been made of the ambient noise field between 25 and 300 Hz with vertical arrays at 32 ° N (124 ° W, 136 ° W, and 150 ° W). Substantial differences in the vertical distribution of noise have been measured, especially at the higher frequencies which can be interpreted in the context of attenuation by seawater sound absorption of coastal shipping. Due to substantial differences in weather at the stations, these measurements also provide an opportunity to observe the effect of weather on the vertical distribution of ambient noise.

I. Introduction

Ambient ocean noise in the low and mid-frequency regions has received a great deal of attention over the last 25 years. Although not intended to be complete, the references provide an indication of the wide scope of this work. In the unclassified literature, major comprehensive bibliographies include [1-4], books [5-8], workshops [9-10], the analysis of experimental data sets [11-43], ship radiated noise characteristics [44-47], theoretical models [48-64], and the performance of array processors operating in an ambient noise environment [65-73]. A representative view into the classified literature can be obtained by reviewing past issues of the U.S. Navy Journal of Underwater Acoustics and the proceedings of the Navy Symposium on Underwater Acoustics.

Downslope conversion of coastal shipping noise has been discussed as being a major contributor to the low-angle noise distribution in the vertical plane (angles close to the horizontal) [33,38-40,42]. If this is so, then sound absorption in seawater should produce changes in the distribution of low-angle noise in the vertical plane as a function of range from coastal shipping.

A decrease in the noise energy per unit angle in the vertical offers improved array performance as a function of distance from coastal shipping. In the Pacific for these latitudes (32° N), the attenuation is about 0.005 dB/km at 300 Hz and decreases to 0.00125 dB/km at 150 Hz. At a range of 1500 nmi (2778 km), the attenuation would be 13.9 dB at 300 Hz and only 3.5 dB at 150 Hz. Therefore, if we had data on vertical noise distribution at short and long ranges from coastal shipping, we would expect to see substantial absolute differences at low angles between the 300 Hz data and much less for the 150 Hz data.

We have made such measurements - two at 32° N 124° W (approximately 350 nmi due west of San Diego), and one each at 32° N 136° W (approximately 1000 nmi west) and 32° N 150° W (approximately 1700 nmi west). Due to substantial differences in weather at the stations, these measurements also provide an opportunity to observe the effect of weather on the vertical distribution of ambient noise.

A summary of the analysis results is contained in this volume (MPL-TM-387-A). Companion volumes (MPL-TM-387-B,C,D,E) contain the complete analysis results for the four data tapes examined (Tapes #85010, 86060, 86247, and 86180, respectively).

For	
<input checked="checked" type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>
on	
n/	
ity Codes	
Dist	Avail and/or Special
A-1	

II. Experiment Description and Data Analysis

The data were obtained with two uniformly spaced arrays suspended in the vertical from FLIP and centered on the sound axis ($z = 750$ m) - the 48 element NORDA VEKA array cut for 309 Hz ($d = 2.4$ m) and the 27 element MPL digital array cut for 217 Hz ($d = 3.46$ m). FLIP was in a tight, three-point moor at 32°N , 124°W for the October 1985 data taken with the NORDA VEKA array and drifting slowly at 32° 124°W , 32° 136°W , and 32° 150°W for the April/May 1986 data taken with the MPL digital array. Figure 1 shows the array deployment geometry superimposed on a representative sound velocity profile. The locations of the FLIP stations are indicated on the chart in Figure 2.

The NORDA VEKA array data discussed here were taken on 18 October 1985 starting at 20:05 PDT (Tape #85010, position 32° 124°W , wind speed 6 kts). Twenty-one data segments each of length 72 s were analyzed (25.2 min total). With a sampling rate $f_s = 907.8$ Hz, each segment consisted of 65536 samples/channel.

Figures 5-6 display the power spectra of Channels #1, 16, 32, and 48 from the first segment of the NORDA VEKA array data (Channel #1 corresponds to the hydrophone at the top of the array). They were derived from the incoherent addition of 15, 50% overlapped, 8192-point FFT's (111 mHz bin width). A Kaiser-Bessel window ($\alpha = 2.5$) weighted the data prior to each FFT. For this value of α , the highest sidelobe level is -57 dB [74]. The values reported in these figures are properly calibrated (dB re 1 $\mu\text{Pa}/\sqrt{\text{Hz}}$). The 90% confidence interval for these results is $\pm 2.0/-1.6$ dB. The very prominent line at slightly less than 250 Hz was projected from a support ship as part of the experiment. The line at 174 Hz was generated on board FLIP.

The MPL digital array data discussed here were taken on 27 April 1986 starting at 06:34 PDT (Tape #86060, position 32° 124°W , wind speed 22 kts), 9 May 1986 starting at 13:38 PDT (Tape #86247, position 32° 136°W , wind speed 17 kts), and 5 May 1986 starting at 10:09 PDT (Tape #86180, position 32° 150°W , wind speed 10 kts). Twenty data segments each of length 55.7 s were analyzed (18.6 min total) from each tape. With a sampling rate of $f_s = 1176$ Hz, each segment consisted of 65536 samples/channel.

Figures 9-10, 13-14, and 17-18 display the power spectra of Channels #1, 10, 20, and 27 from the first segment of each of the MPL digital array data tapes (Channel #1 corresponds to the hydrophone at the top of the array). They were derived from the incoherent addition of 15, 50% overlapped, 8192-point FFT's (144 mHz bin width). A Kaiser-Bessel window ($\alpha = 2.5$) weighted the data prior to each FFT. The values reported in these figures are properly calibrated (dB re 1 $\mu\text{Pa}/\sqrt{\text{Hz}}$). The 90% confidence interval for these results is +2.0/-1.6 dB.

The results in the next section were produced with a FFT beamformer [75]. The along-channel FFT's were 50% overlapped and 8192-points in length. A Kaiser-Bessel window ($\alpha = 2.5$) weighted the data prior to each FFT. The cross-channel FFT's were 512-points in length where the (complex) data first was windowed with a 48-point (NORDA VEKA array data) or a 27-point (MPL digital array data) Kaiser-Bessel window ($\alpha = 1.5$) and then zero-padded out to the FFT length. For this value of α , the first sidelobe is -35 dB [74]. Figures 3-4 display the beam patterns of both arrays at several frequencies.

III. Discussion

Figures 7-8, 11-12, 15-16, and 19-20 report the time-evolving character of ambient noise vertical directionality at three stations due west of San Diego. Tape #85010 is from the NORDA VEKA array at 124° W. Tapes #86060, 86247, and 86180 are from the MPL digital array at 124° W, 136° W, and 150° W, respectively. The waterfall plots represent a (time) FFT bin width of 111 mHz (NORDA VEKA array) and 144 mHz (MPL digital array) centered every 25 Hz from 25 Hz through 300 Hz. Multi-panel plots of the same results are included for $f = 75$ Hz, $f = 150$ Hz, and $f = 300$ Hz. Positive angles refer to downward looking beams. The plots have been calibrated to report ambient noise power spectral density per Hz per degree of vertical angle (dB re $1 \mu\text{Pa}/\sqrt{\text{HzDeg}}$).

A number of observations can be made by comparing the waterfall and multi-panel plots from the three stations. Under calm weather conditions (Tapes #85010 and #86180), the vertical distribution of ambient noise clearly is concentrated within approximately $\pm 15^\circ$ of the horizontal. Under poor weather conditions (Tape #86060), high wind speed has the effect of filling in the higher vertical angles while leaving the level within the low-angular region unchanged. Under intermediate weather conditions (Tape #86247), a transition between these two characteristics occurs which is frequency dependent (in the case of Tape #86247, the transition occurs in the the 125-150 Hz region). This frequency-dependent transition characteristic is consistent with single hydrophone measurements reported in the literature (e.g. see [24] where ambient noise levels above 100 Hz were very sensitive to wind speed while ambient noise levels below 100 Hz showed no wind speed dependence at all).

In the low-angular region at the higher frequencies, significant differences can be seen in the vertical distribution of ambient noise as a function of distance from the coast. There is a clear decrease in absolute level with distance. Furthermore, a concave character to the angular distribution of ambient noise centered on the horizontal begins to appear. Both of these observations are consistent with the hypothesis that downslope conversion of coastal shipping noise constitutes a major portion of the low-angle energy and that this kind of noise is diminished by sound absorption as a function of distance from the coast.

IV. Summary

Downslope conversion of coastal shipping noise has been discussed as being a major contributor to the low-angle noise distribution in the vertical plane (angles close to the horizontal). The results reported here on the vertical directionality of ambient noise as a function of longitude are consistent with this hypothesis. Sound absorption in seawater appears to diminish the low-angle energy as a function of distance from the coast with the effect being more pronounced at higher frequencies than at lower frequencies.

Due to substantial differences in weather at the stations, these measurements also provided an opportunity to observe the effect of weather on the vertical distribution of ambient noise. Under calm weather conditions, the vertical distribution of ambient noise clearly is concentrated within approximately $\pm 15^\circ$ of the horizontal. Under poor weather conditions, high wind speed has the effect of filling in the higher vertical angles while leaving the level within the low-angular region unchanged. Under intermediate weather conditions, a frequency-dependent transition between these two characteristics occurs which is consistent with single hydrophone measurements of wind speed dependence.

Acknowledgements

This work was supported by the Office of Naval Research under contract N00014-84-K-0097 and the Naval Air Systems Command under contract N00014-87-C-0127. The NORDA VEKA array was augmented by Neptune Ocean Engineering under the supervision of Dr. Tom Tunnell of NORDA. Dr. Tunnell was in charge of the NORDA and Neptune Ocean Engineering personnel which included Cecil Watkins and Andrew Monks of NORDA and Dr. Norman Gholson and Tony Jarrell of Neptune. Subcontracts from MPL to NORDA and Neptune Ocean Engineering were let in order to collect the data discussed here. Dr. Fred Fisher was chief scientist for CONTRACK VIII and IX and Dr. Bill Hodgkiss was in charge of data analysis. We wish to thank Mr. Dewitt Efird, the Officer-in-Charge of FLIP and his crew for their excellent cooperation.

References

- [1] G.M. Wenz, "Review of Underwater Acoustics Research: Noise," J. Acoust. Soc. Am. 51:3(2):1010-1024 (1972).
- [2] W. Crouch, "Ambient Sea Noise: A Review of the Literature," NUSC TR-4179, Naval Underwater Systems Center, New London, CT (1972).
- [3] R.A. Wagstaff, "A Comprehensive Ambient Noise Bibliography," NUC TR-333, Naval Undersea Center, San Diego, CA (1973).
- [4] Terry E. Ingalsbe, "The Ambient Noise Bibliographic Data Bank," AESD TN-75-03, Acoustic Environmental Support Detachment, Office of Naval Research, Arlington, VA (1975).
- [5] D. Ross, "Mechanics of Underwater Noise," Pergamon Press (1976).
- [6] R.J. Urick, "Sound Propagation in the Sea," Defense Advanced Research Projects Agency, Washington, DC (1979).
- [7] R.J. Urick. Principles of Underwater Sound. NY: McGraw-Hill, 1983.
- [8] R.J. Urick, "Ambient Noise in the Sea," Undersea Warfare Technology Office, Naval Sea Systems Command, Dept. of the Navy, Washington, DC (1984).
- [9] "International Workshop on Low-Frequency Propagation and Noise." 14-19 October 1974. Woods Hole, MA (Coordinated by the Maury Center for Ocean Science, Office of Naval Research).
- [10] R.A. Wagstaff and O.Z. Bluy, "Proceedings SACLANTCEN Conference on Underwater Ambient Noise," 15 June 1982 La Spezia, Italy.
- [11] G.M. Wenz, "Acoustic Ambient Noise in the Ocean: Spectra and Sources," J. Acoust. Soc. Am. 34(2): 1936-1956 (1962).
- [12] G.R. Fox, "Ambient-Noise Directivity Measurements," J. Acoust. Soc. Am. 36(3): 1537-1540 (1964).
- [13] R.J. Talham, "Ambient-Sea-Noise Model," J. Acoust. Soc. Am. 36(8): 1541-1544 (1964).
- [14] C.L. Piggott, "Ambient Sea Noise at Low Frequencies in shallow Water off the Scotian Shelf," J. Acoust. Soc. Am. 36(11): 2152-2163 (1964).

- [15] E.H. Axelrod, B.A. Schoomer, and W.A. Von Winkle, "Vertical Directionality of Ambient Noise in the Deep Ocean at a Site near Bermuda," *J. Acoust. Soc. Am.* 37(1): 77-83 (1965).
- [16] R. Rudnick and E.D. Squier, "Fluctuations and Directionality in Ambient Sea Noise," *J. Acoust. Soc. Am.* 41(5): 1347-1351 (1967).
- [17] A.J. Perrone, "Deep-ocean ambient-noise spectra in the northwest Atlantic," *J. Acoust. Soc. Am.* 46: 762-770 (1969).
- [18] A.J. Perrone, "Ambient noise spectrum levels as a function of water-depth," *J. Acoust. Soc. Am.* 48: 362-370 (1970).
- [19] A.J. Perrone, "Infrasonic and low-frequency ambient noise measurements on the Grand Banks," *J. Acoust. Soc. Am.* 55: 754-758 (1974).
- [20] R. Martin and A. Perrone, "Geographical variation of ambient noise in the ocean for the frequency range from 1 Hz to 5 kHz," *International Workshop on Low-Frequency Propagation and Noise*, Vol. 2, 14-19 October 1974, Woods Hole, MA, pp. 817-841.
- [21] G. B. Morris, "Preliminary Results on Seamount and Continental Slope Reflection Enhancement of Shipping Noise," MPL-U-57/75, Marine Physical Laboratory, Scripps Institution of Oceanography, San Diego, CA (1975).
- [22] A.C. Kibblewhite, J.A. Shooter, and S.L. Watkins, "Examination of attenuation at very low frequencies using the deep-water ambient noise field," *J. Acoust. Soc. Am.* 60(5): 1040-1047 (1976).
- [23] D.H. Cato, "Ambient sea noise in waters near Australia," *J. Acoust. Soc. Am.* 60(2): 320-328 (1976).
- [24] G. B. Morris, "Depth dependence of ambient noise in the northeast Pacific Ocean," *J. Acoust. Soc. Am.* 64: 581-590 (1978).
- [25] R.A. Wagstaff, "Iterative technique for ambient-noise horizontal-directionality estimation from towed line-array data," *J. Acoust. Soc. Am.* 63(3): 863-869 (1978).
- [26] V.C. Anderson, "Envelope spectra for signals and noise in vertically directional beams," *J. Acoust. Soc. Am.* 65(6): 1480-1487 (1979).

- [27] V.C. Anderson, "Variation of the vertical directionality of noise with depth in the North Pacific," *J. Acoust. Soc. Am.* 66(5): 1446-1452 (1979).
- [28] R.W. Bannister, R. N. Denham, K. M. Guthrie, D. G. Browning, A. J. Perrone, "Variability of low-frequency ambient sea noise," *J. Acoust. Soc. Am.* 65: 1156-1163 (1979).
- [29] V.C. Anderson, "Nonstationary and nonuniform oceanic background in a high-gain acoustic array," *J. Acoust. Soc. Am.* 67(4): 1170-1179 (1980).
- [30] W.S. Hodgkiss and V.C. Anderson, "Detection of sinusoids in ocean acoustic background noise," *J. Acoust. Soc. Am.* 67(1): 214-219 (1980).
- [31] R.A. Wagstaff, "Horizontal directionality estimation considering array tilt and noise field vertical arrival structure," *J. Acoust. Soc. Am.* 67(4): 1287-1294 (1980).
- [32] J.A. Shooter and M. Gentry, "Wind generated noise in the Parece Vela Basin," *J. Acoust. Soc. Am.* 70(6): 1757-1761 (1981).
- [33] R.A. Wagstaff, "Low-frequency ambient noise in the deep sound channel - The missing component," *J. Acoust. Soc. Am.* 69(4): 1009-1014 (1981).
- [34] S.C. Wales and O.I. Diachok, "Ambient noise vertical directionality in the northwest Atlantic," *J. Acoust. Soc. Am.* 70(2): 577-582 (1981).
- [35] R.C. Tyce, "Depth Dependence of Directionality of Ambient Noise in the North Pacific: Experimental Data And Equipment Design," SACLANTCEN Conference Proceedings No. 32 (Underwater Ambient Noise), 15 June 1982, SACLANT ASW Research Centre, San Bartolomeo, Italy.
- [36] A.S. Burgess and D.J. Kewley, "Wind-generated surface noise source levels in deep water east of Australia," *J. Acoust. Soc. Am.* 73(1): 201-210 (1983).
- [37] W.A. Kuperman and M.C. Ferla, "A shallow water experiment to determine the source spectrum level of wind-generated noise," *J. Acoust. Soc. Am.* 77(6): 2067-2073 (1985).
- [38] W.M. Carey, R.A. Wagstaff, B.A. Brunson, and M.R. Bradley, "Low-Frequency Noise Fields and Signal Characteristics," NORDA TR-131, Naval Ocean Research and Development Activity.

NSTL, MS (1985).

- [39] W.M. Carey and R.A. Wagstaff, "Low-frequency noise fields," J. Acoust. Soc. Am. 80(5): 1523-1526 (1986).
- [40] W.M. Carey, "Measurement of down-slope sound propagation from a shallow source to a deep ocean receiver," J. Acoust. Soc. Am. 79(1): 49-59 (1986).
- [41] R.W. Bannister, "Deep sound channel noise from high-latitude winds," J. Acoust. Soc. Am. 79(1): 41-48 (1986).
- [42] W.M. Carey, I.B. Gereben, and B.A. Brunson, "Measurement of sound propagation downslope to a bottom-limited sound channel," J. Acoust. Soc. Am. 81(2): 244-257 (1987).
- [43] M.J. Buckingham, "A new shallow-ocean technique for determining the critical angle of the seabed from the vertical directionality of the ambient noise in the water column," J. Acoust. Soc. Am. 81(4): 938-946 (1987).
- [44] J. Cybulski, "Probable Origin of Measured Supertanker Radiated Noise Spectra," Oceans '77, pp. 15c-1 to 15c-8 (1977).
- [45] B. Schmalfeldt and D. Rauch, "Ambient and Ship-Induced Low-Frequency Noise in Shallow Water," appears in: W. Kuperman and F. Jensen, "Bottom-Interacting Ocean Acoustics," pp. 329-343, NY: Plenum Press (1980).
- [46] L.M. Gray and D.S. Greeley, "Source level model for propeller blade rate radiation for the world's merchant fleet," J. Acoust. Soc. Am. 67(2): 516-522 (1980).
- [47] J.C. Heine, "Acoustic Source Characteristics of Merchant Ships," SACLANTCEN Conference Proceedings No. 32 (Underwater Ambient Noise), 15 June 1982, SACLANT ASW Research Centre, San Bartolomeo, Italy.
- [48] W.S. Liggett and M.J. Jacobson, "Covariance of Noise in Attenuating Media," J. Acoust. Soc. Am. 36: 1183-1194 (1964).
- [49] W.S. Liggett and M.J. Jacobson, "Covariance of Surface-Generated Noise in a Deep Ocean," J. Acoust. Soc. Am. 38: 303-312 (1965).

- [50] H. Cox, "Spatial correlation in arbitrary noise fields with application to ambient sea noise," J. Acoust. Soc. Am. 54(5): 1289-1301 (1973).
- [51] H. Cox, "Spatial correlation in arbitrary noise fields with application to ambient sea noise," J. Acoust. Soc. Am. 54(5): 1289-1301 (1973).
- [52] W.A. Kuperman and F. Ingenito, "Spatial correlation of surface generated noise in a stratified ocean," J. Acoust. Soc. Am. 67(6): 1988-1996 (1980).
- [53] M.J. Buckingham, "A theoretical model of ambient noise in a low-loss, shallow water channel," J. Acoust. Soc. Am. 67(4): 1186-1192 (1980).
- [54] R.C. Cavanagh and W.W. Renner, "Vertical directionality and depth dependence of averaged acoustic signals and noise," J. Acoust. Soc. Am. 68(5): 1467-1474 (1980).
- [55] D.E. Weston, "Ambient noise depth-dependence models and their relation to low-frequency attenuation," J. Acoust. Soc. Am. 67(2): 530-537 (1980).
- [56] C.I. Oelkers, "Noise correlation functions for arbitrary receiver orientation and steering direction in vertically anisotropic, azimuthally isotropic noise fields," J. Acoust. Soc. Am. 67(3): 864-867 (1980).
- [57] R.J. Talham, "Noise correlation functions for anisotropic noise fields," J. Acoust. Soc. Am. 69(1): 213-214 (1981).
- [58] R.J. Talham, "Noise correlation functions for anisotropic noise fields," J. Acoust. Soc. Am. 69(1): 213-214 (1981).
- [59] M.J. Buckingham, "Spatial coherence of wind-generated noise in a shallow ocean channel," J. Acoust. Soc. Am. 70(5): 1412-1420 (1981).
- [60] R.A. Wagstaff, "Noise Field Calculation or Measurement Simulation: Some Comments on Ambient Noise Modeling," Oceans '82, pp. 187-191 (1982).
- [61] D. Ross, "Role of Propagation in Ambient Noise," SACLANTCEN Conference Proceedings No. 32 (Underwater Ambient Noise), 15 June 1982, SACLANT ASW Research Centre, San Bartolomeo, Italy.

- [62] J.H. Wilson, "Wind-generated noise modeling," J. Acoust. Soc. Am. 73(1):211-216 (1983).
- [63] R. Dashen and W. Munk, "Three models of ocean noise," J. Acoust. Soc. Am. 76(2): 540-554 (1984).
- [64] M.J. Buckingham, "A theoretical model of surface-generated noise in a wedge-shaped ocean with pressure-release boundaries," J. Acoust. Soc. Am. 78(1): 143-148 (1985).
- [65] H. Cox, "Line array performance when the signal coherence is spatially dependent," J. Acoust. Soc. Am. 54(6): 1743-1746 (1973).
- [66] E.R. Floyd and D.F. Gordon, "Effects of Propagation on Linear Array Performance," NUC TN 1774, Naval Undersea Center, San Diego, CA (1976).
- [67] M.J. Buckingham, "On the response of steered vertical line arrays to anisotropic noise," Proc. R. Soc. Lond. A 367: 539-547 (1979).
- [68] M.J. Buckingham, "Array gain of a broadside vertical line array in shallow water," J. Acoust. Soc. Am. 65(1): 148-161 (1979).
- [69] R.M. Hamson, "The theoretical gain limitations of a passive vertical line array in shallow water," J. Acoust. Soc. Am. 68(1): 156-164 (1980).
- [70] F. Ingenito, "Calculations of the Spatial coherence and Array Noise Gain of Wind-Generated Noise," Oceans '82, pp. 166-171 (1982).
- [71] M.J. Buckingham, "On the response of a towed array to the acoustic field in shallow water," IEE Proc 131 F (3): 298-307 (1984).
- [72] R.M. Hamson, "The theoretical responses of vertical and horizontal line arrays to wind-induced noise in shallow water," J. Acoust. Soc. Am. 78(5): 1702-1712 (1985).
- [73] B.G. Ferguson and D.V. Wyllie, "Comparison of observed and theoretical responses of a horizontal line array to wind-induced noise in the deep ocean," J. Acoust. Soc. Am. 82(2): 601-605 (1987).
- [74] F.J. Harris, "On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform," Proc. IEEE 66(1): 51-83 (1978).
- [75] J.R. Williams, "Fast Beam-Forming Algorithm," J. Acoust. Soc. Am. 44(5): 1454-1455 (1968).

Figure Captions

- Figure 1. Array Deployment Geometry and Representative Sound Velocity Profile.
- Figure 2. FLIP Stations for October 1985 and April/May 1986 Experiments.
- Figure 3. Beam Patterns: NORDA VEKA Array. (a) Kaiser-Bessel ($\alpha = 1.5$) shading function and (b) Rectangular shading function.
- Figure 4. Beam Patterns: MPL Digital Array. (a) Kaiser-Bessel ($\alpha = 1.5$) shading function and (b) Rectangular shading function.
- Figure 5. Power Spectra: Tape #85010. FFT Bin Width = 111 mHz. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$. Channels #1, 16, 32, and 48.
- Figure 6. Power Spectra: Tape #85010. FFT Bin Width = 111 mHz. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$. (a) Channel #1, (b) Channel #16, (c) Channel #32, and (d) Channel #48.
- Figure 7. Ambient Noise Vertical Directionality: Tape #85010. 32° N 124° W. Wind speed 6 kts. 18 October 1985, 20:05 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: dB// μ Pa/ $\sqrt{\text{HzDeg}}$. (a) $f = 25$ Hz, (b) $f = 50$ Hz, (c) $f = 75$ Hz, (d) $f = 100$ Hz, (e) $f = 125$ Hz, (f) $f = 150$ Hz, (g) $f = 175$ Hz, (h) $f = 200$ Hz, (i) $f = 225$ Hz, (j) $f = 250$ Hz, (k) $f = 275$ Hz, and (l) $f = 300$ Hz.
- Figure 8. Ambient Noise Vertical Directionality: Tape #85010. 32° N 124° W. Wind speed 6 kts. 18 October 1985, 20:05 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: dB// μ Pa/ $\sqrt{\text{HzDeg}}$. (a) $f = 75$ Hz, (b) $f = 150$ Hz, and (c) $f = 300$ Hz.
- Figure 9. Power Spectra: Tape #86060. FFT Bin Width = 144 mHz. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$. Channels #1, 10, 20, and 27.

- Figure 10. Power Spectra: Tape #86060. FFT Bin Width = 144 mHz. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$. (a) Channel #1, (b) Channel #10, (c) Channel #20, and (d) Channel #27.
- Figure 11. Ambient Noise Vertical Directionality: Tape #86060. 32° N 124° W. Wind speed 22 kts. 27 April 1986, 06:34 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$ Deg. (a) $f = 25$ Hz, (b) $f = 50$ Hz, (c) $f = 75$ Hz, (d) $f = 100$ Hz, (e) $f = 125$ Hz, (f) $f = 150$ Hz, (g) $f = 175$ Hz, (h) $f = 200$ Hz, (i) $f = 225$ Hz, (j) $f = 250$ Hz, (k) $f = 275$ Hz, and (l) $f = 300$ Hz.
- Figure 12. Ambient Noise Vertical Directionality: Tape #86060. 32° N 124° W. Wind speed 22 kts. 9 May 1986, 13:38 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$ Deg. (a) $f = 75$ Hz, (b) $f = 150$ Hz, and (c) $f = 300$ Hz.
- Figure 13. Power Spectra: Tape #86247. FFT Bin Width = 144 mHz. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$. Channels #1, 10, 20, and 27.
- Figure 14. Power Spectra: Tape #86247. FFT Bin Width = 144 mHz. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$. (a) Channel #1, (b) Channel #10, (c) Channel #20, and (d) Channel #27.
- Figure 15. Ambient Noise Vertical Directionality: Tape #86247. 32° N 136° W. Wind speed 17 kts. 9 May 1986, 13:38 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$ Deg. (a) $f = 25$ Hz, (b) $f = 50$ Hz, (c) $f = 75$ Hz, (d) $f = 100$ Hz, (e) $f = 125$ Hz, (f) $f = 150$ Hz, (g) $f = 175$ Hz, (h) $f = 200$ Hz, (i) $f = 225$ Hz, (j) $f = 250$ Hz, (k) $f = 275$ Hz, and (l) $f = 300$ Hz.
- Figure 16. Ambient Noise Vertical Directionality: Tape #86247. 32° N 136° W. Wind speed 17 kts. 9 May 1986, 13:38 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: dB// μ Pa/ $\sqrt{\text{Hz}}$ Deg. (a) $f = 75$ Hz, (b) $f = 150$ Hz, and (c) $f = 300$ Hz.

Figure 17. Power Spectra: Tape #86180. FFT Bin Width = 144 mHz. Calibration:

$\text{dB}/\mu\text{Pa}/\sqrt{\text{Hz}}$. Channels #1, 10, 20, and 27.

Figure 18. Power Spectra: Tape #86180. FFT Bin Width = 144 mHz. Calibration:

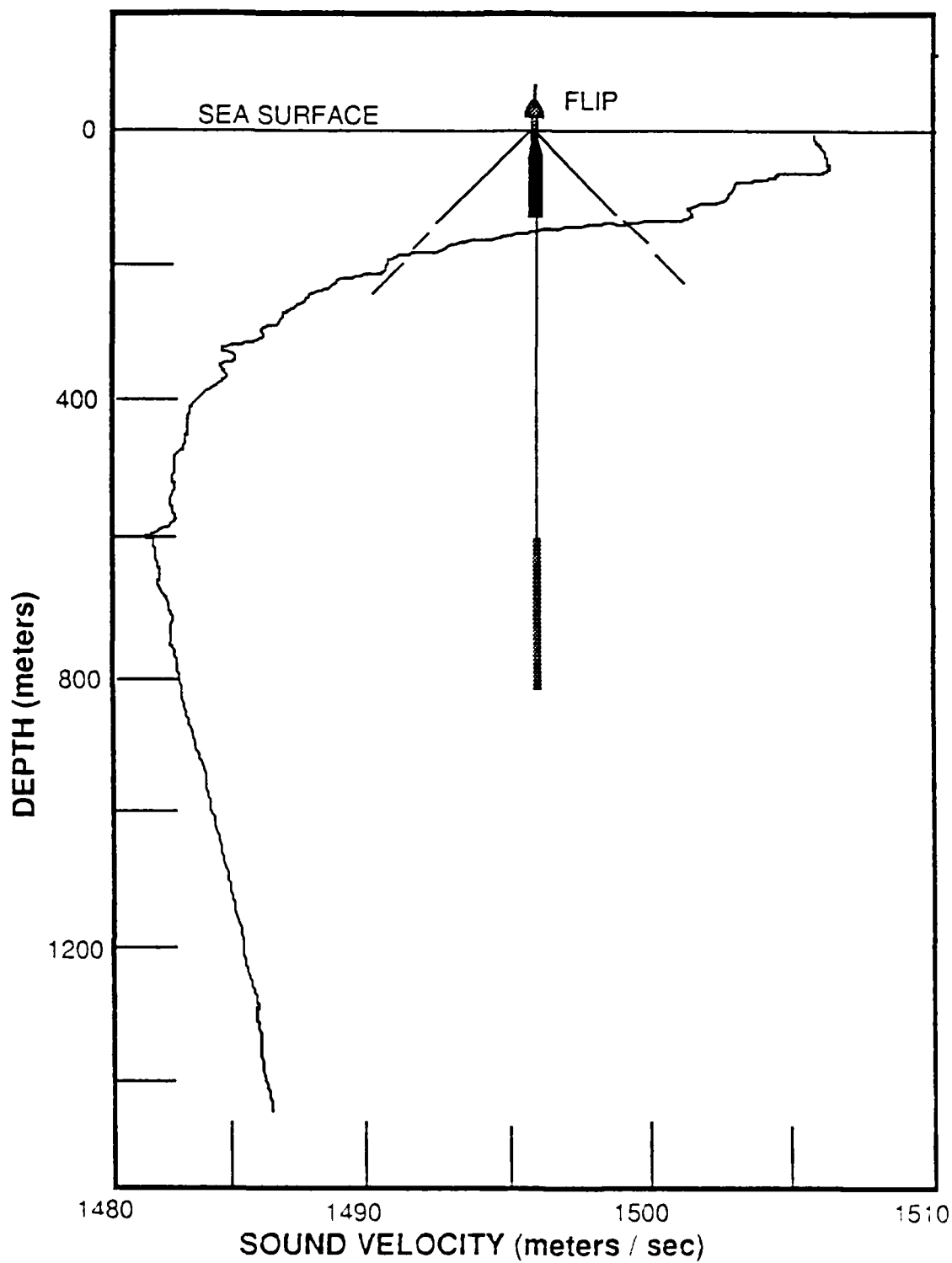
$\text{dB}/\mu\text{Pa}/\sqrt{\text{Hz}}$. (a) Channel #1, (b) Channel #10, (c) Channel #20, and (d) Channel #27.

Figure 19. Ambient Noise Vertical Directionality: Tape #86180. $32^\circ\text{N } 150^\circ\text{W}$. Wind speed 10

kts. 5 May 1986, 10:09 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: $\text{dB}/\mu\text{Pa}/\sqrt{\text{HzDeg}}$. (a) $f = 25\text{ Hz}$, (b) $f = 50\text{ Hz}$, (c) $f = 75\text{ Hz}$, (d) $f = 100\text{ Hz}$, (e) $f = 125\text{ Hz}$, (f) $f = 150\text{ Hz}$, (g) $f = 175\text{ Hz}$, (h) $f = 200\text{ Hz}$, (i) $f = 225\text{ Hz}$, (j) $f = 250\text{ Hz}$, (k) $f = 275\text{ Hz}$, and (l) $f = 300\text{ Hz}$.

Figure 20. Ambient Noise Vertical Directionality: Tape #86180. $32^\circ\text{N } 150^\circ\text{W}$. Wind speed 10

kts. 5 May 1986, 10:09 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: $\text{dB}/\mu\text{Pa}/\sqrt{\text{HzDeg}}$. (a) $f = 75\text{ Hz}$, (b) $f = 150\text{ Hz}$, and (c) $f = 300\text{ Hz}$.



Hawaii to California

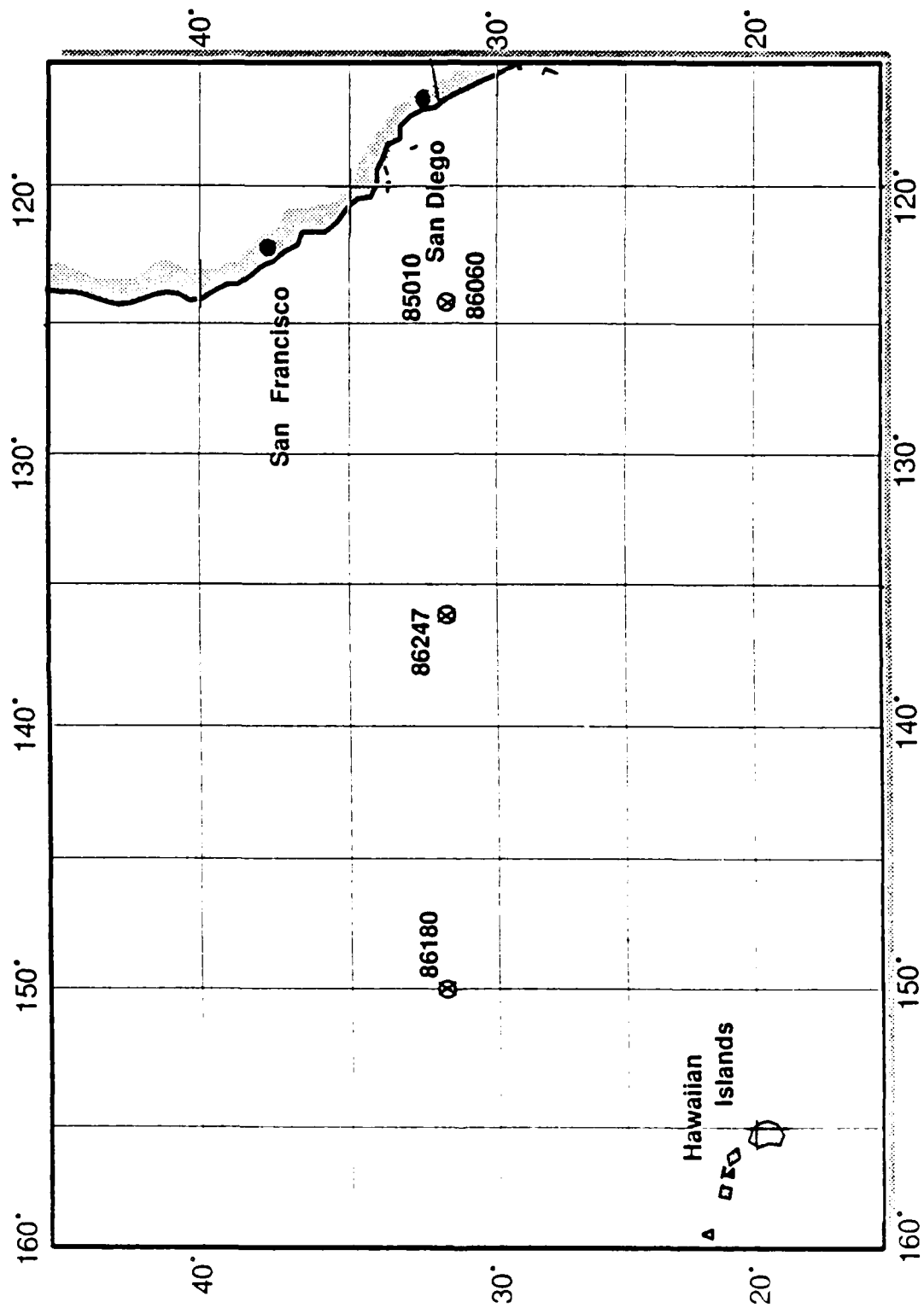


Figure 2.

VLFN Array Beam Pattern: kb window ($\alpha = 1.5$)

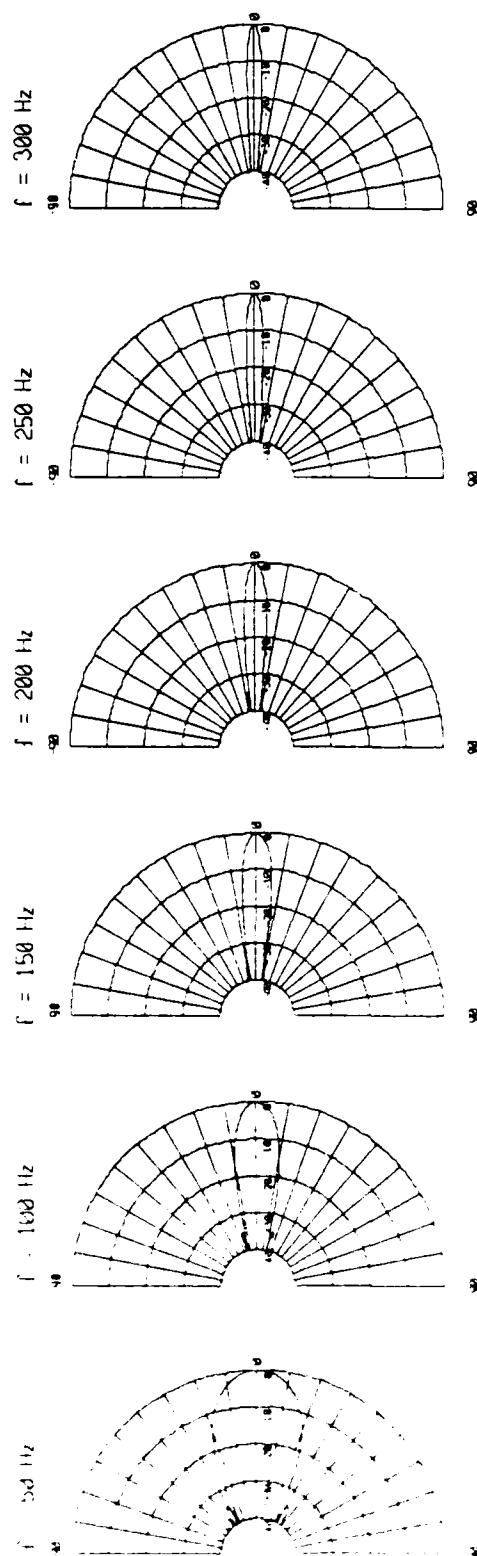


Figure 3(a).

VLFN Array Beam Pattern: rect window

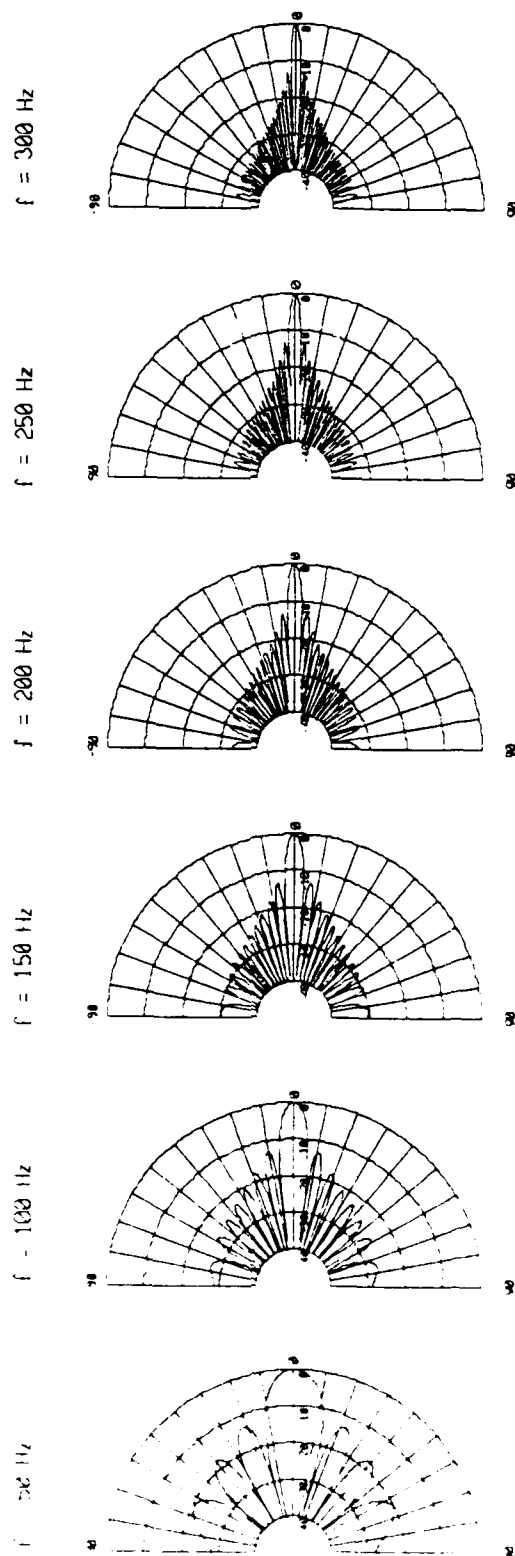


Figure 3(b).

HPA Array Beam Pattern: kb window ($\alpha = 1.5$)

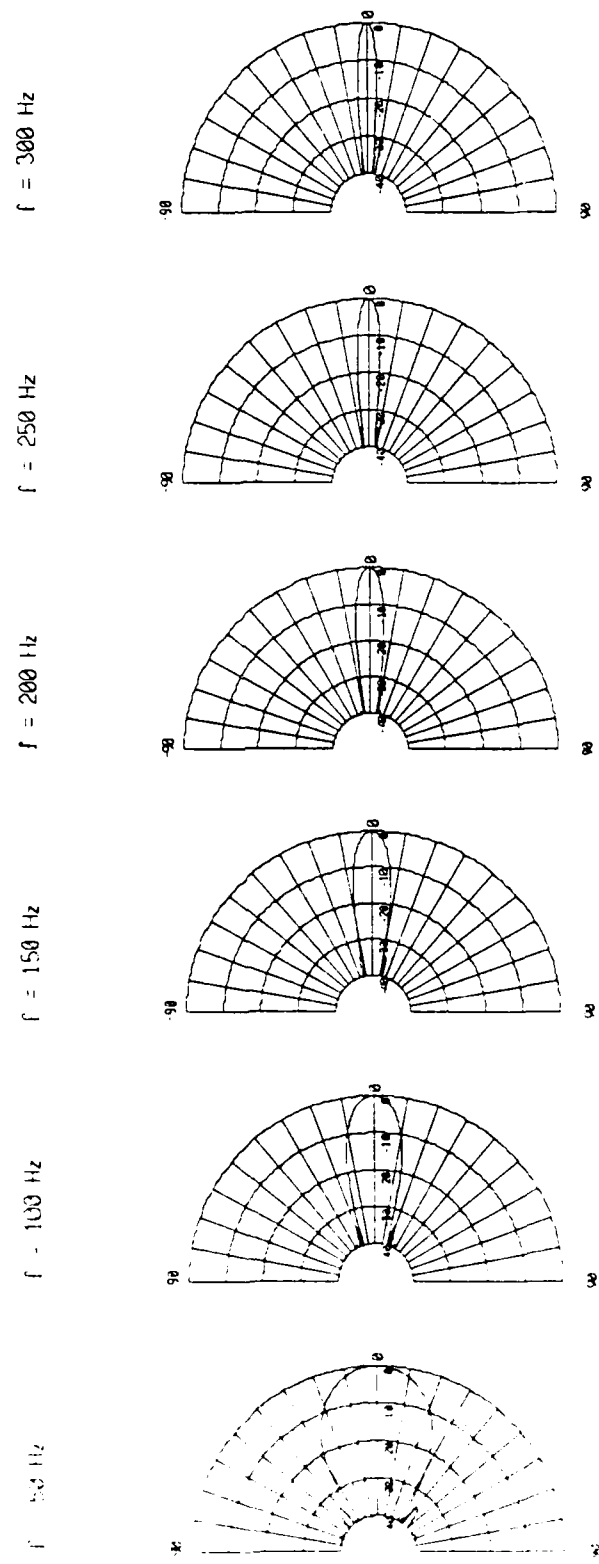


Figure 4(a).

MMA Array Beam Pattern: rect window

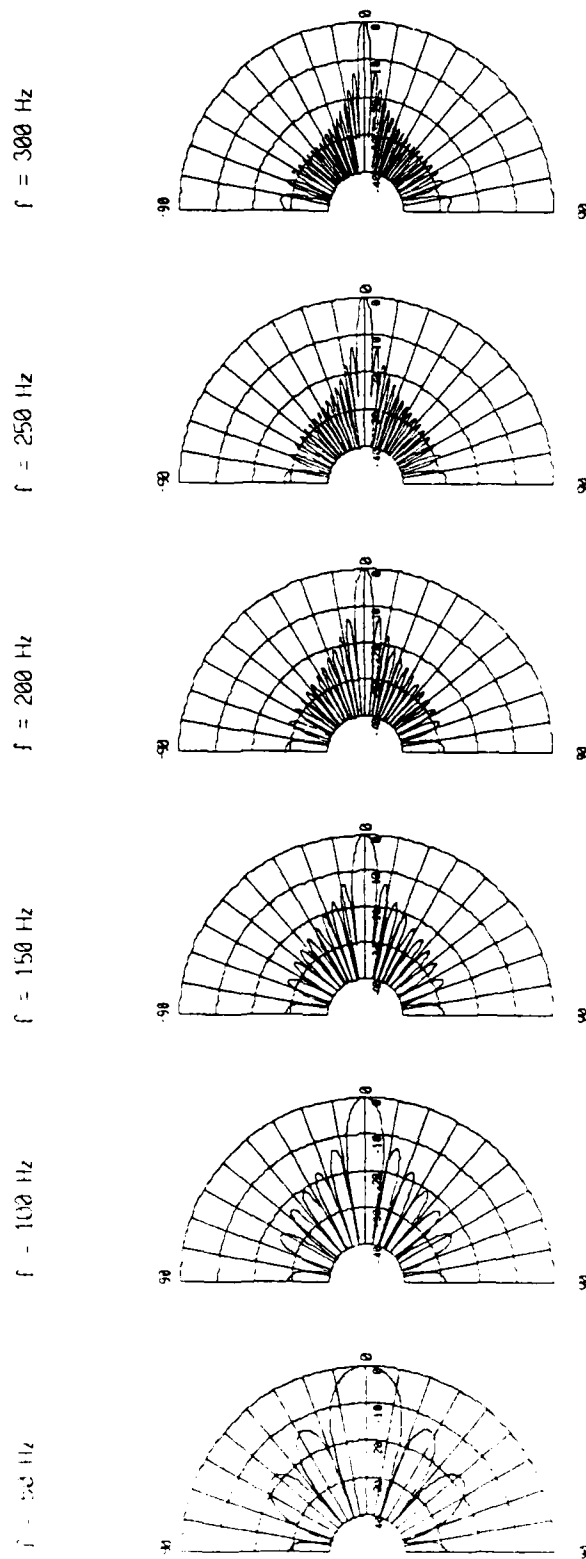


Figure 4(b).

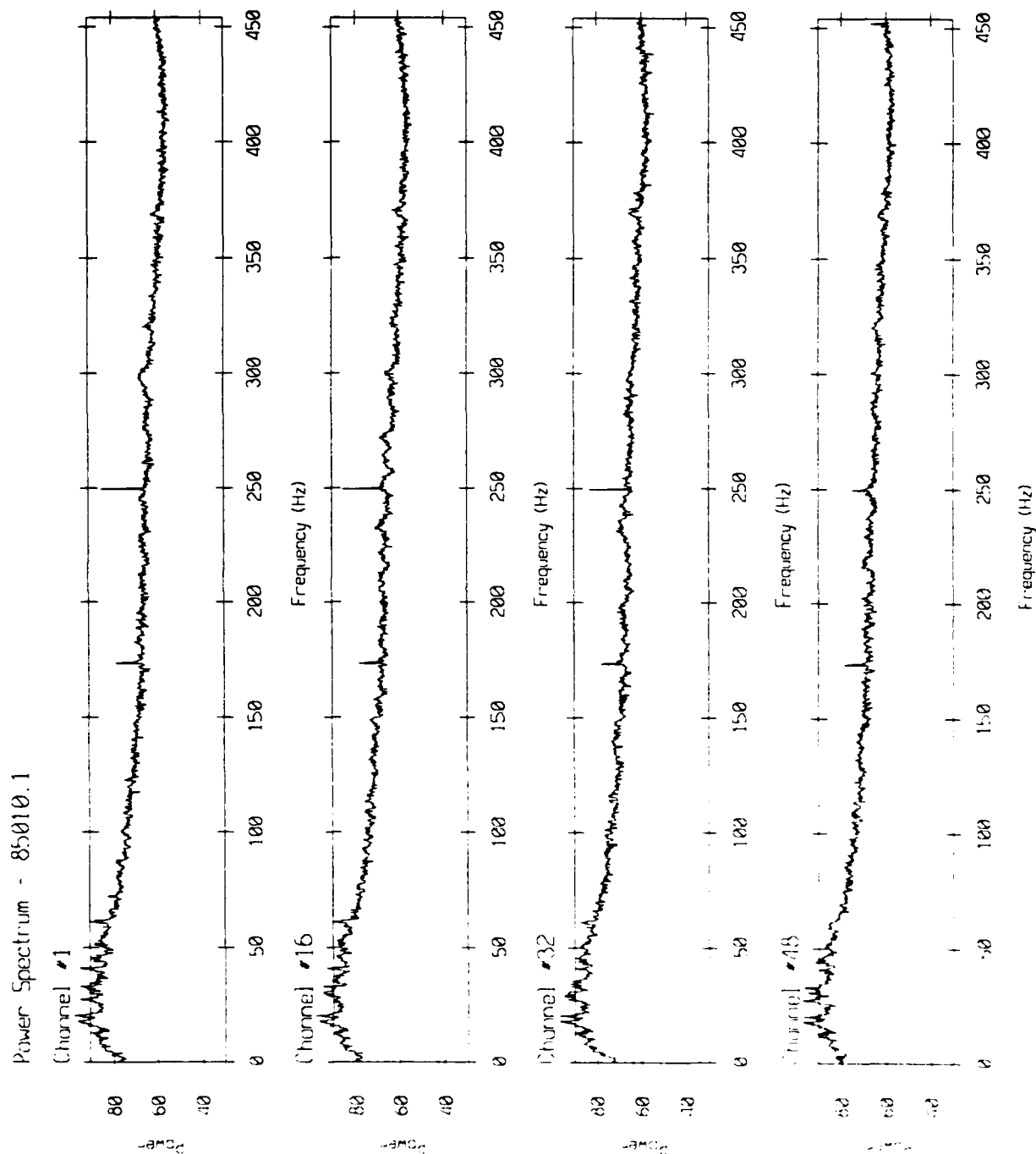
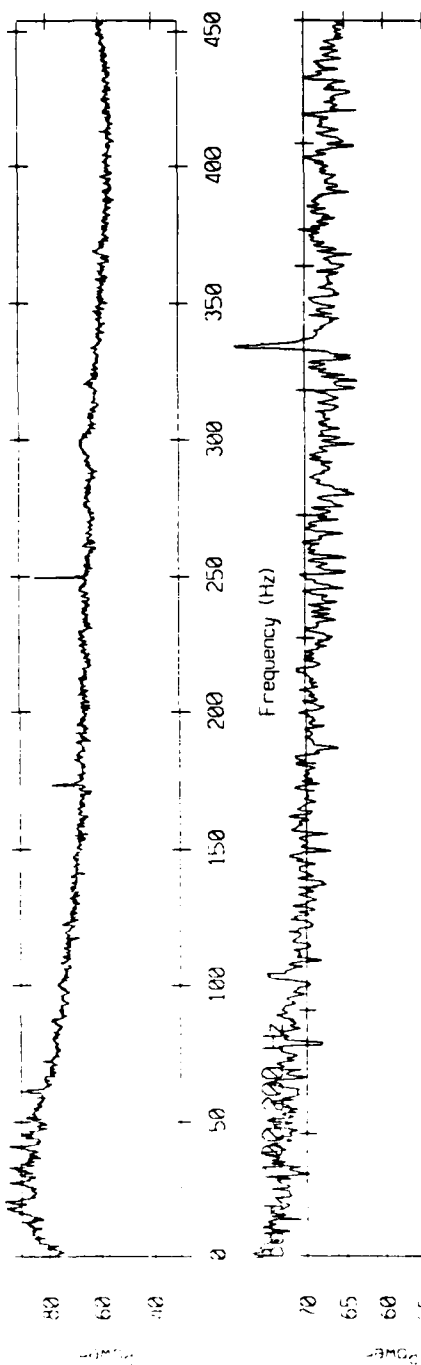


Figure 5.

Power Spectrum - 85010.1 Channel #1

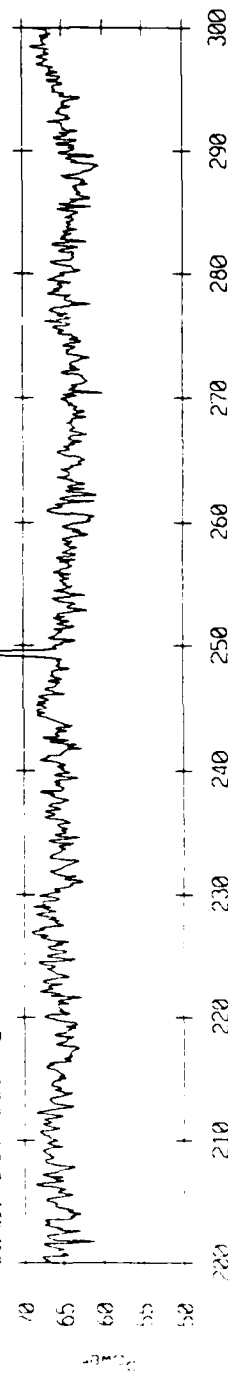
Band: 0 450 Hz



Frequency (Hz)

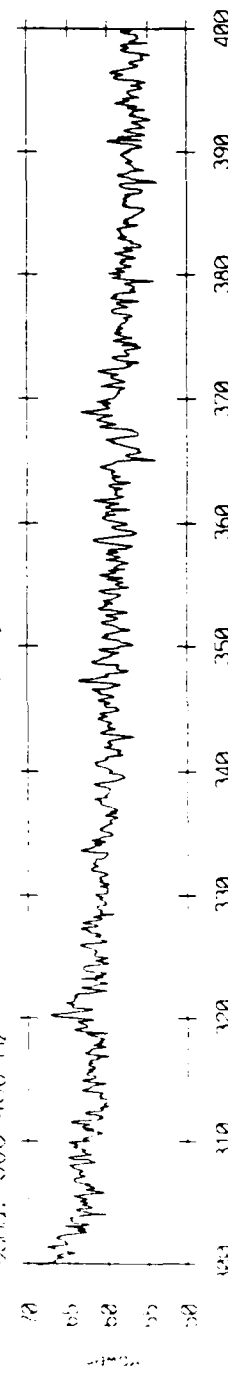
25

band: 200 300 Hz



Frequency (Hz)

band: 300 400 Hz



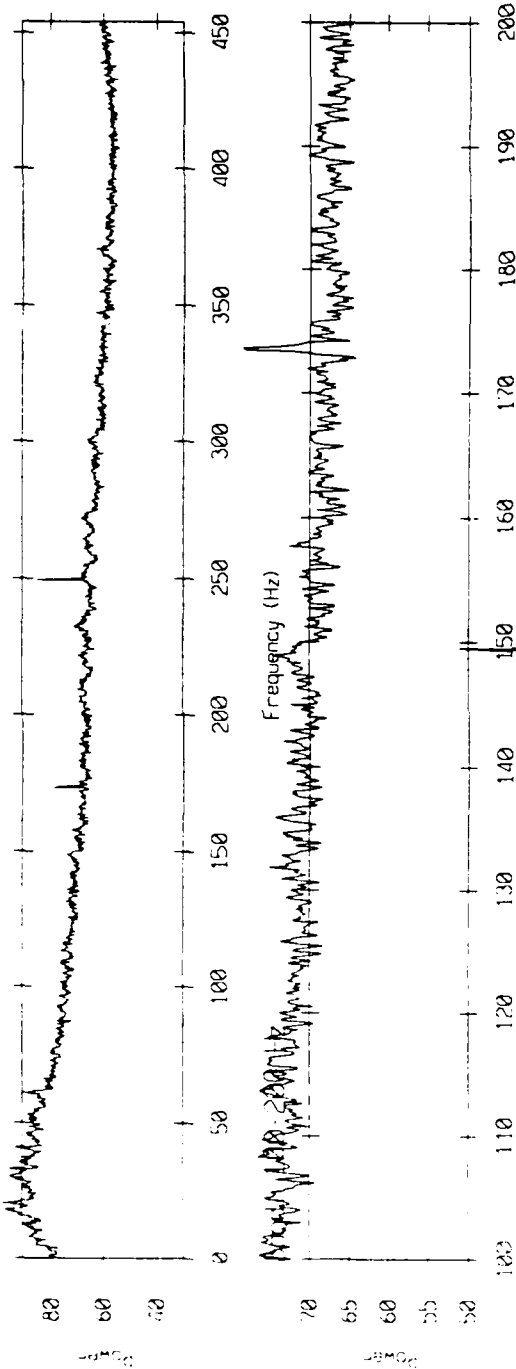
Frequency (Hz)

Frequency (Hz)

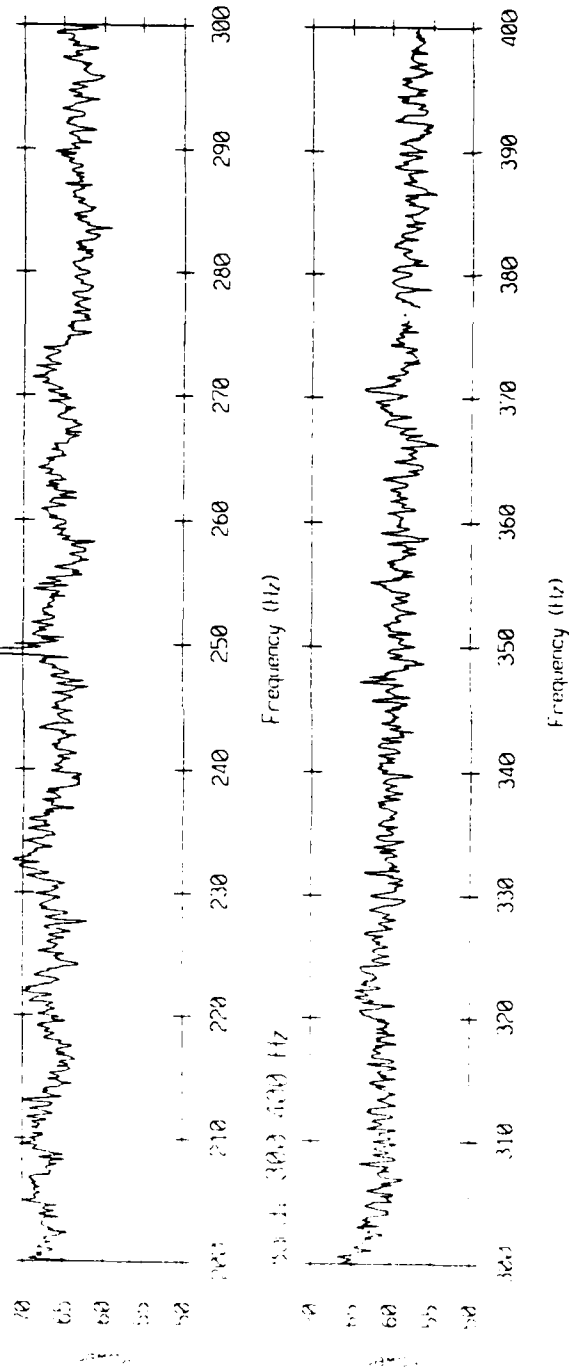
Figure 6(a).

Power Spectrum - 85010.1 Channel 16

Band: 0 450 Hz



Band: 200 300 Hz



Band: 300 400 Hz

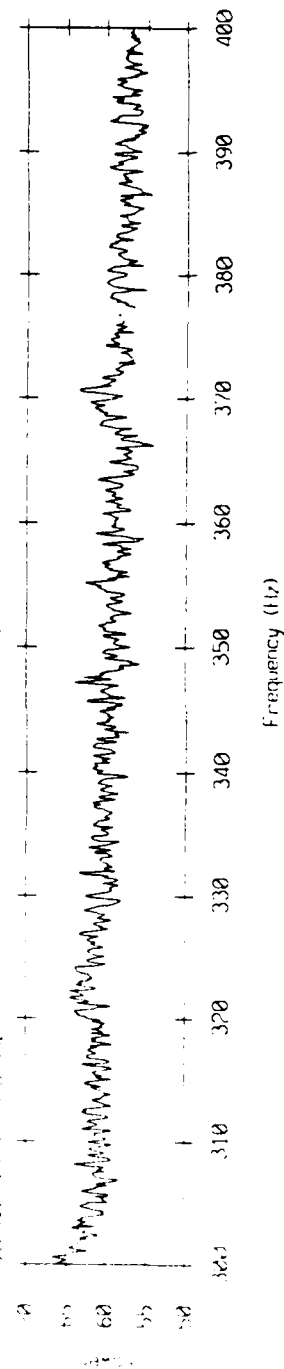
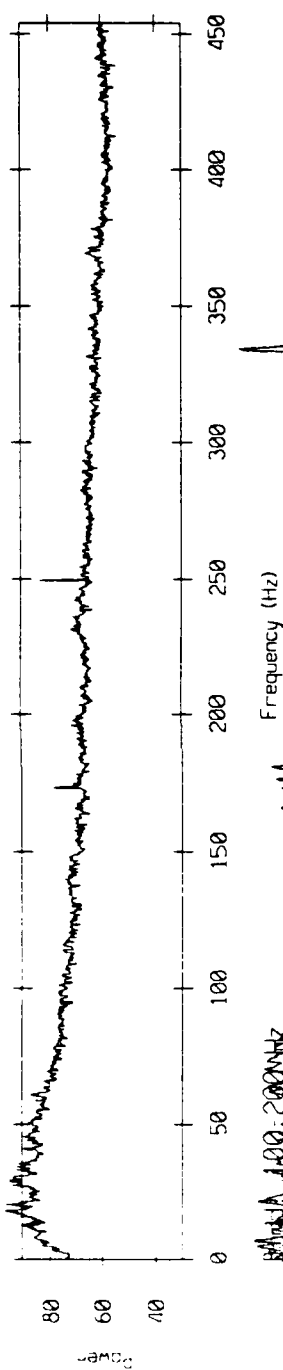


Figure 6(b).

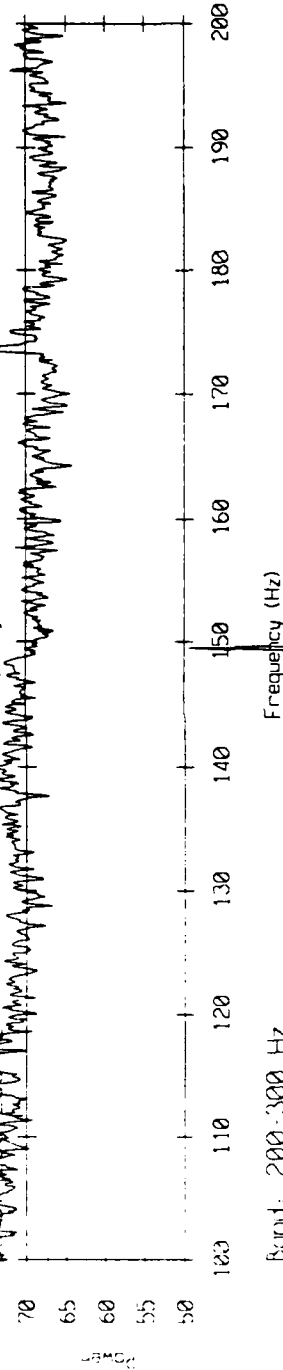
Power Spectrum - 85010.1 Channel #32

Band: 0-450 Hz



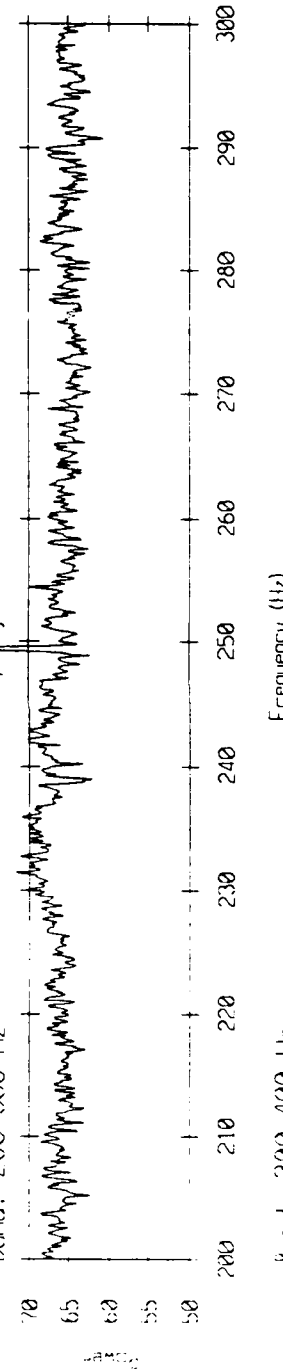
Frequency (Hz)

Band: 200-300 Hz



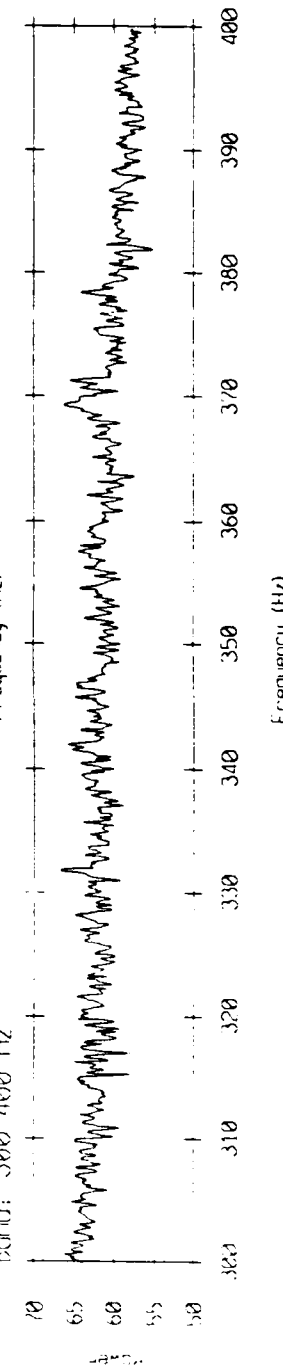
Frequency (Hz)

Band: 300-400 Hz



Frequency (Hz)

Band: 300-400 Hz

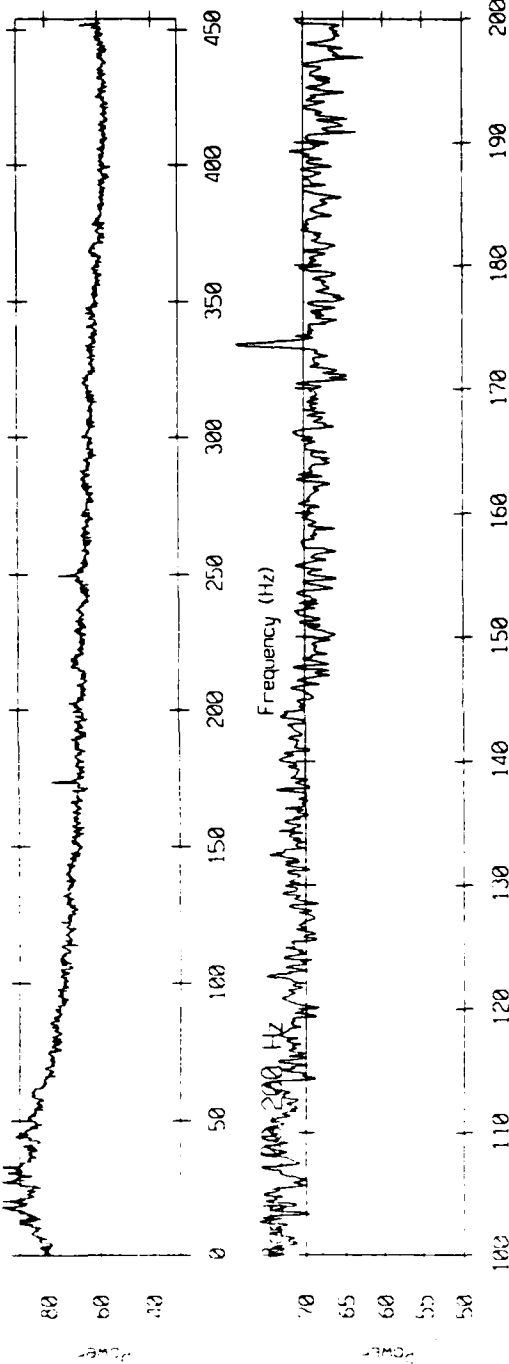


Frequency (Hz)

Figure 6(c).

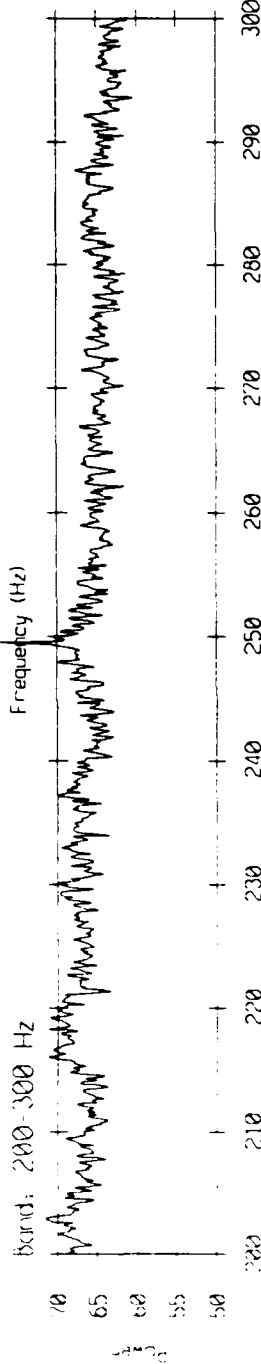
Power Spectrum - 85010.1 Channel #48

Band: 0 450 Hz



12

Band: 200-300 Hz



Band: 300 400 Hz

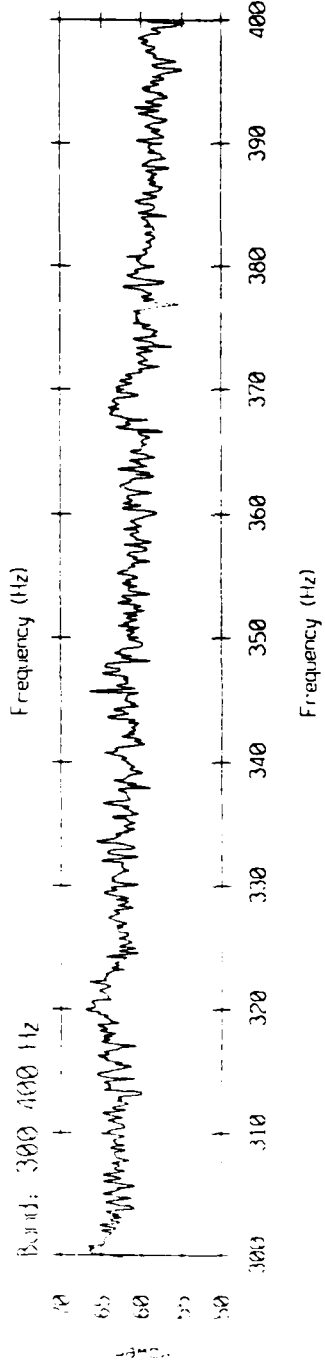
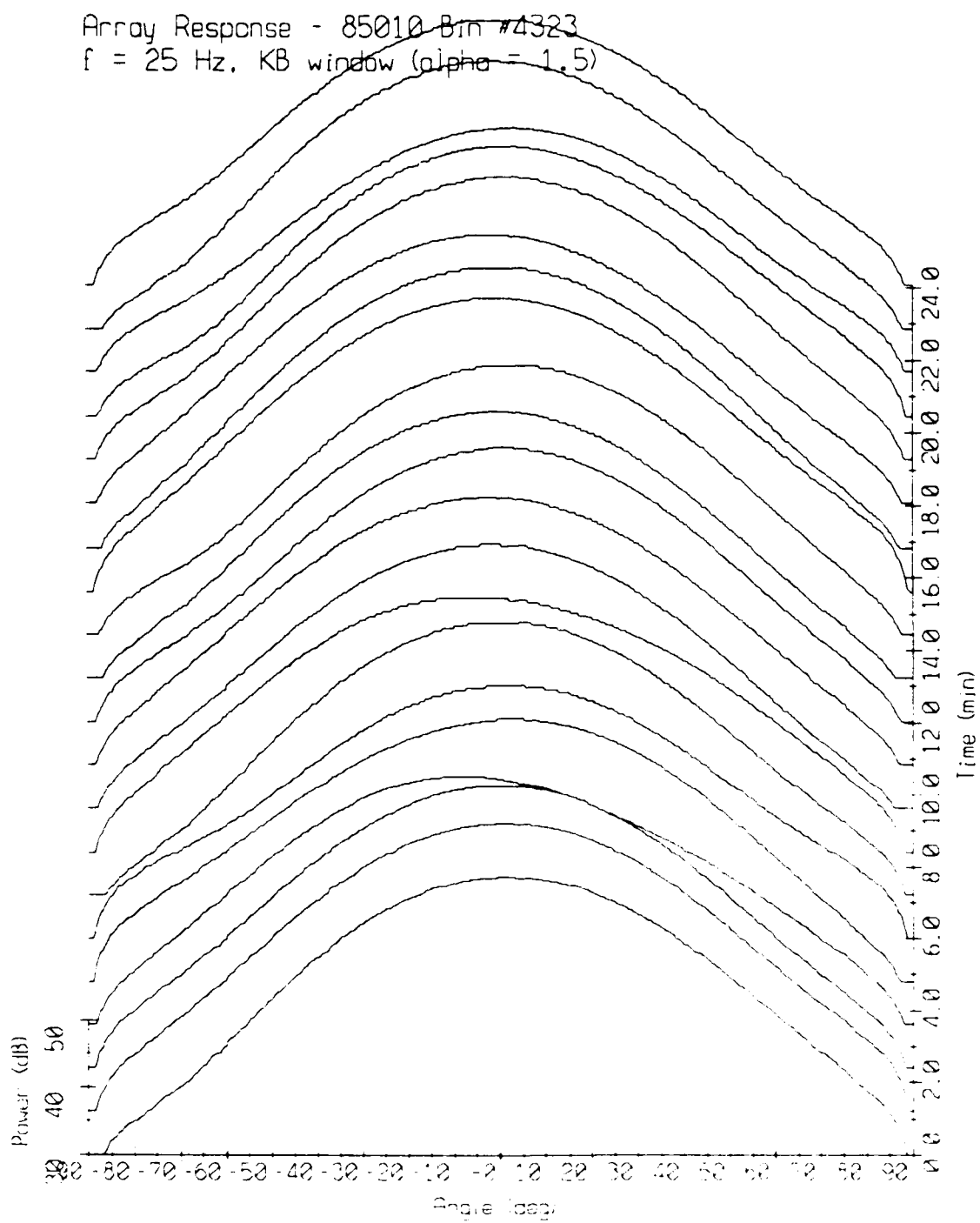
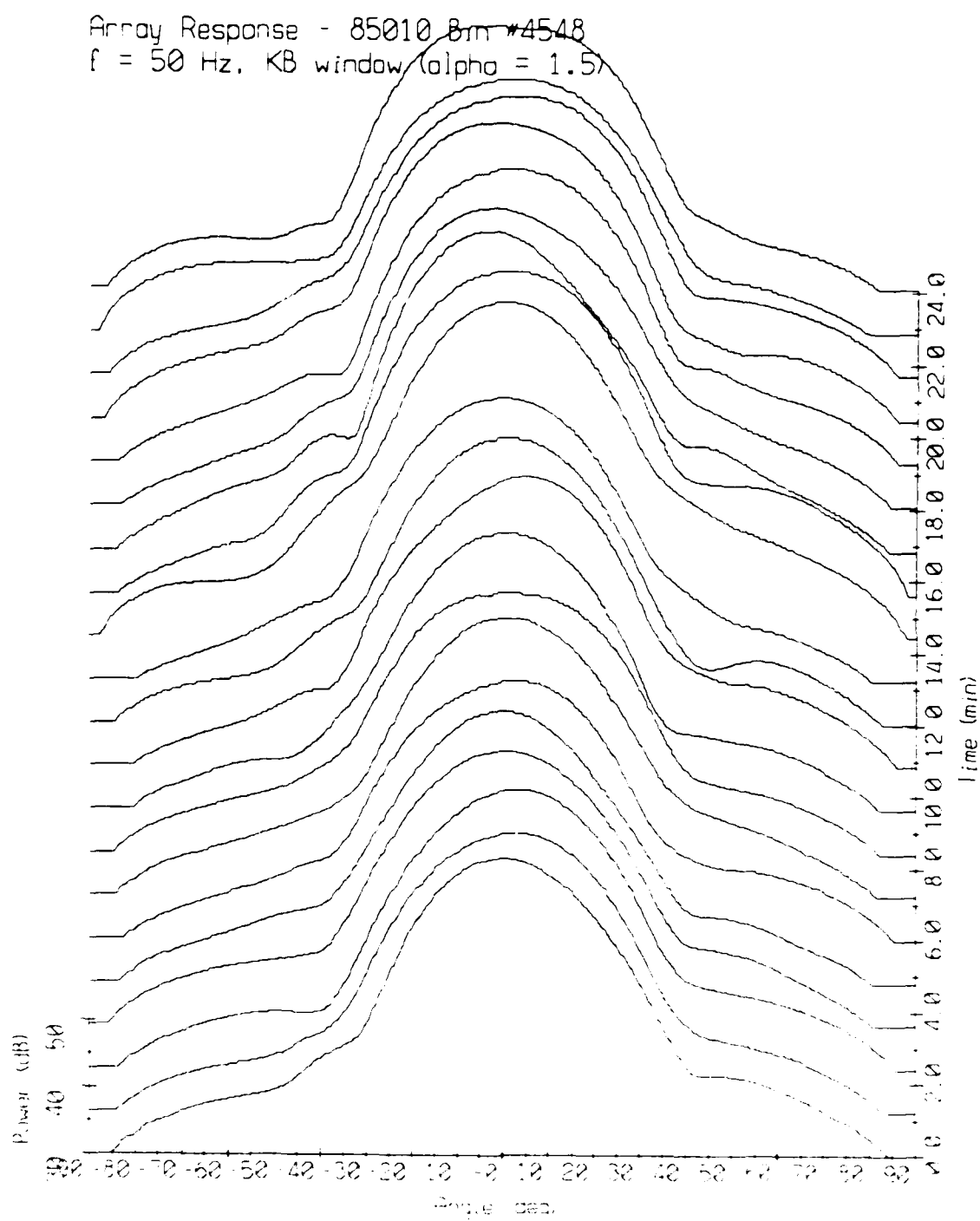
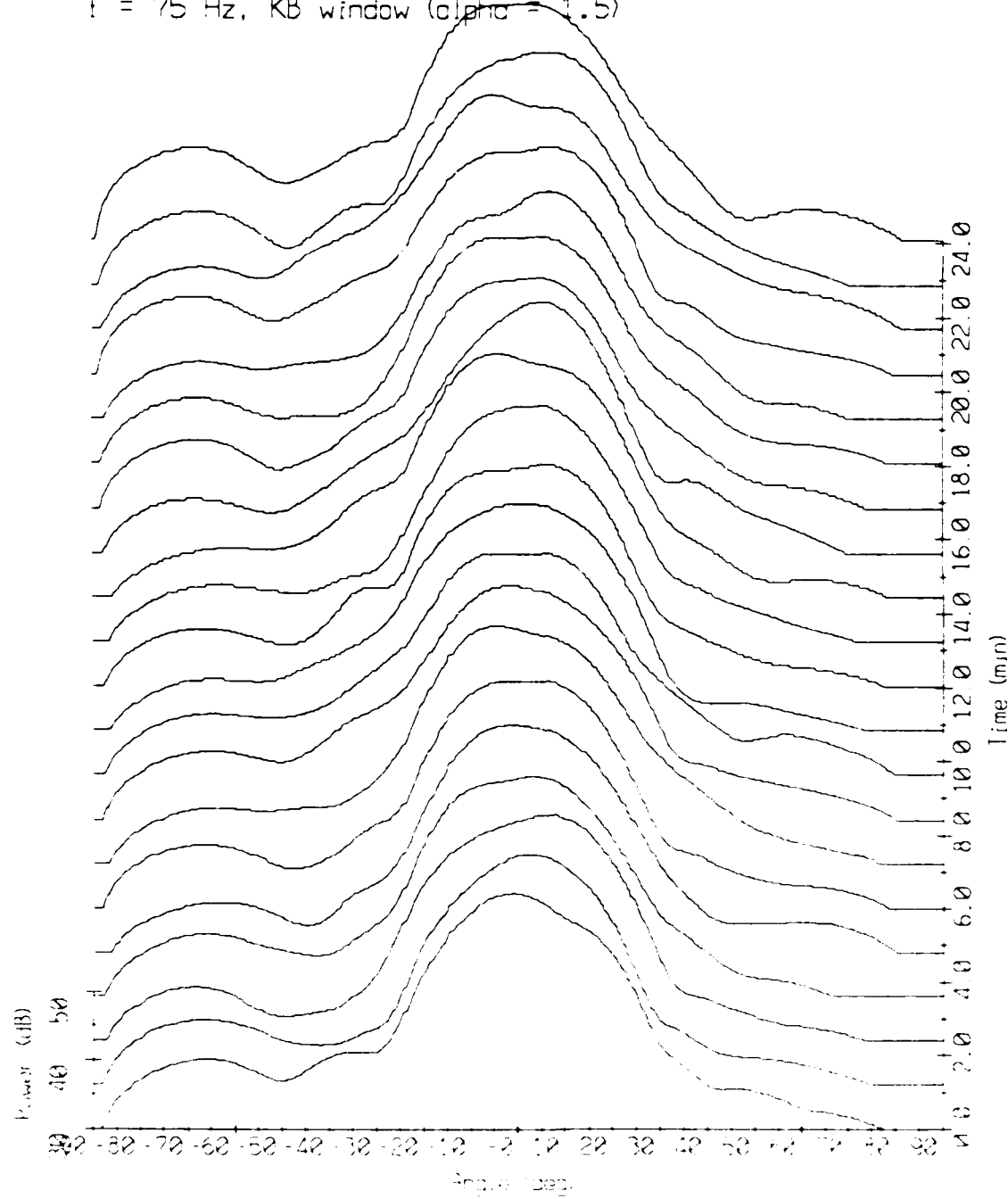


Figure 6(d).

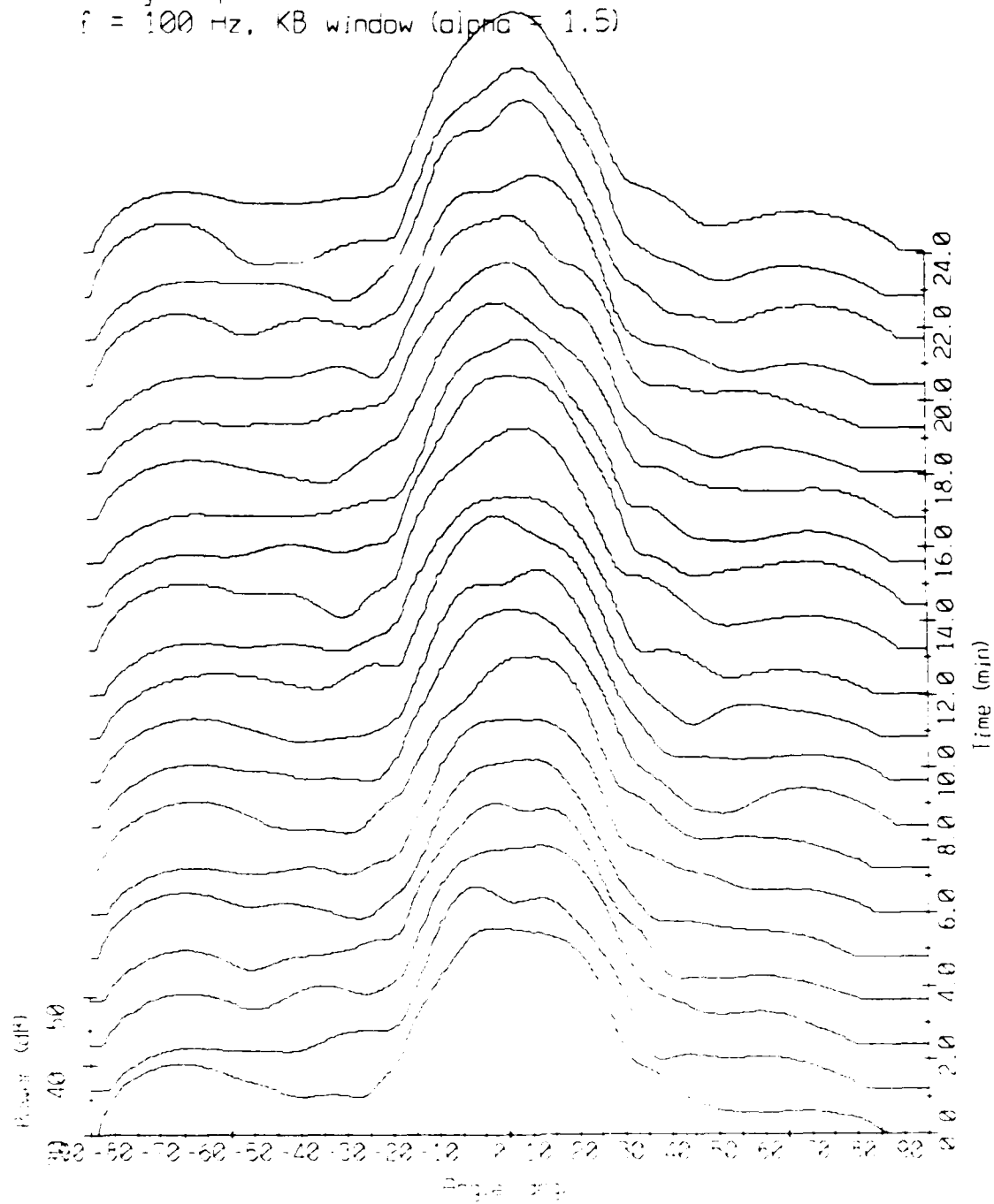




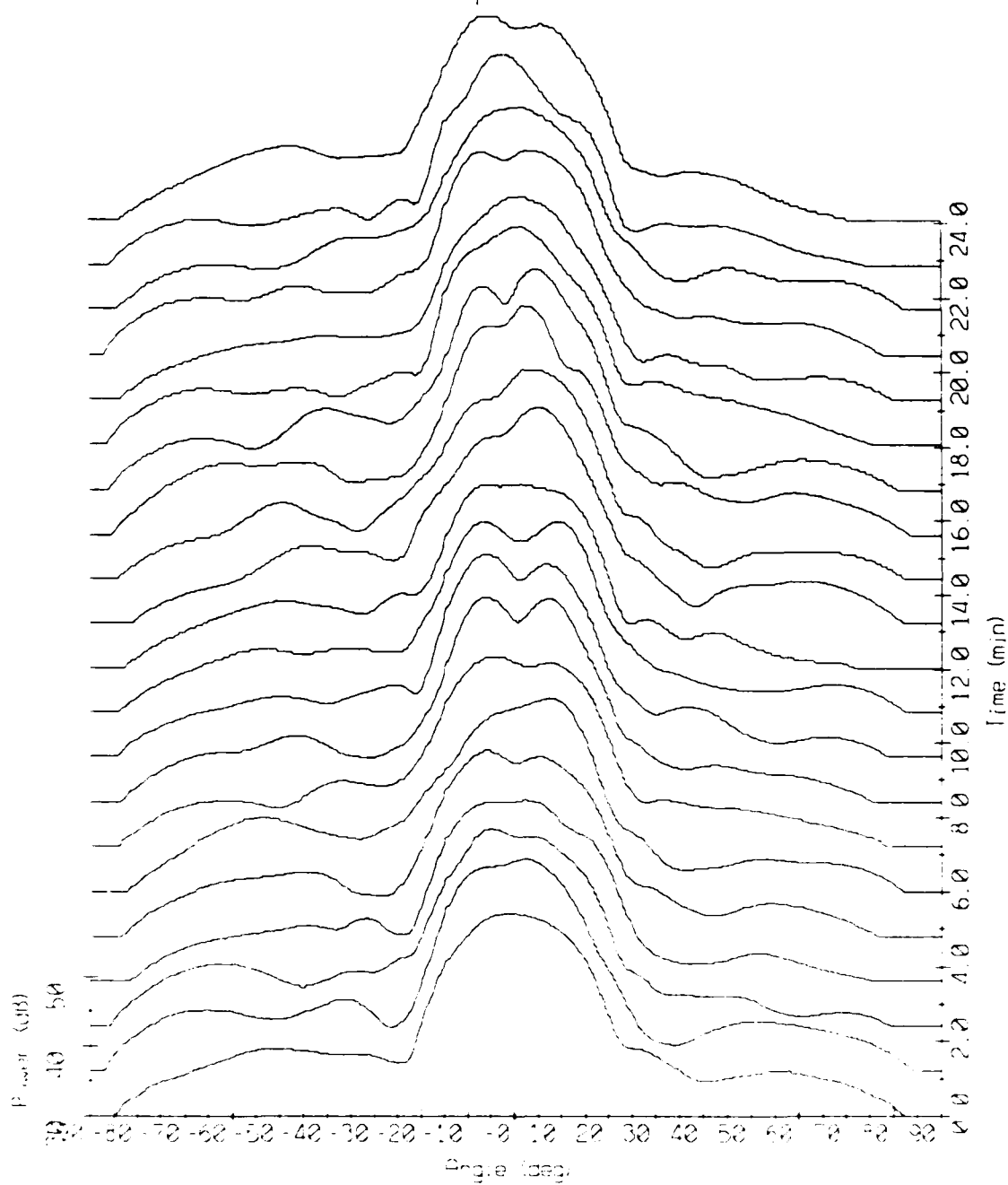
Array Response - 85010 Bin #4774
 $f = 75$ Hz, KB window ($\alpha = 1.5$)



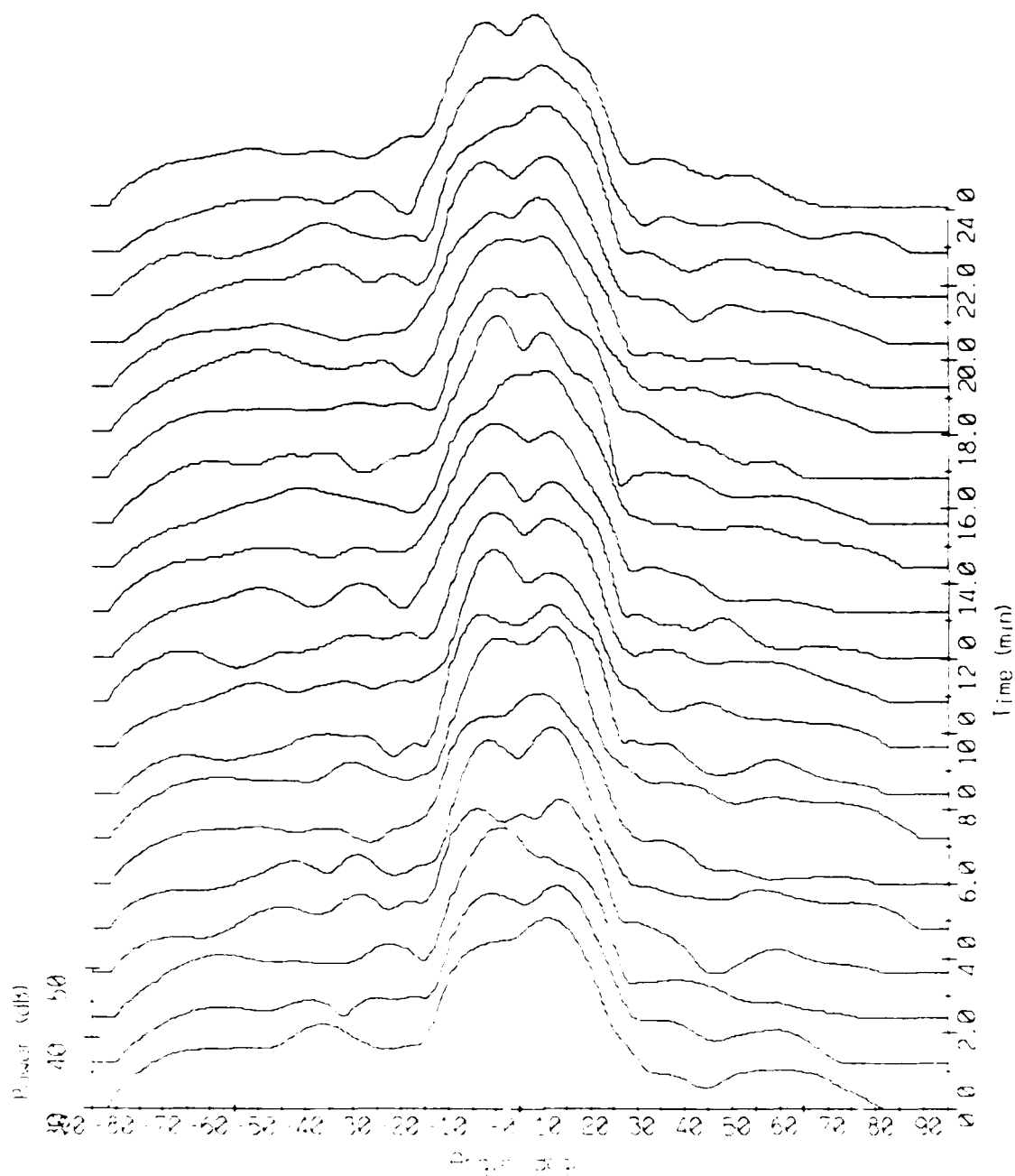
Array Response - 85010 Bin #4999
 $f = 100$ Hz, KB window ($\alpha = 1.5$)



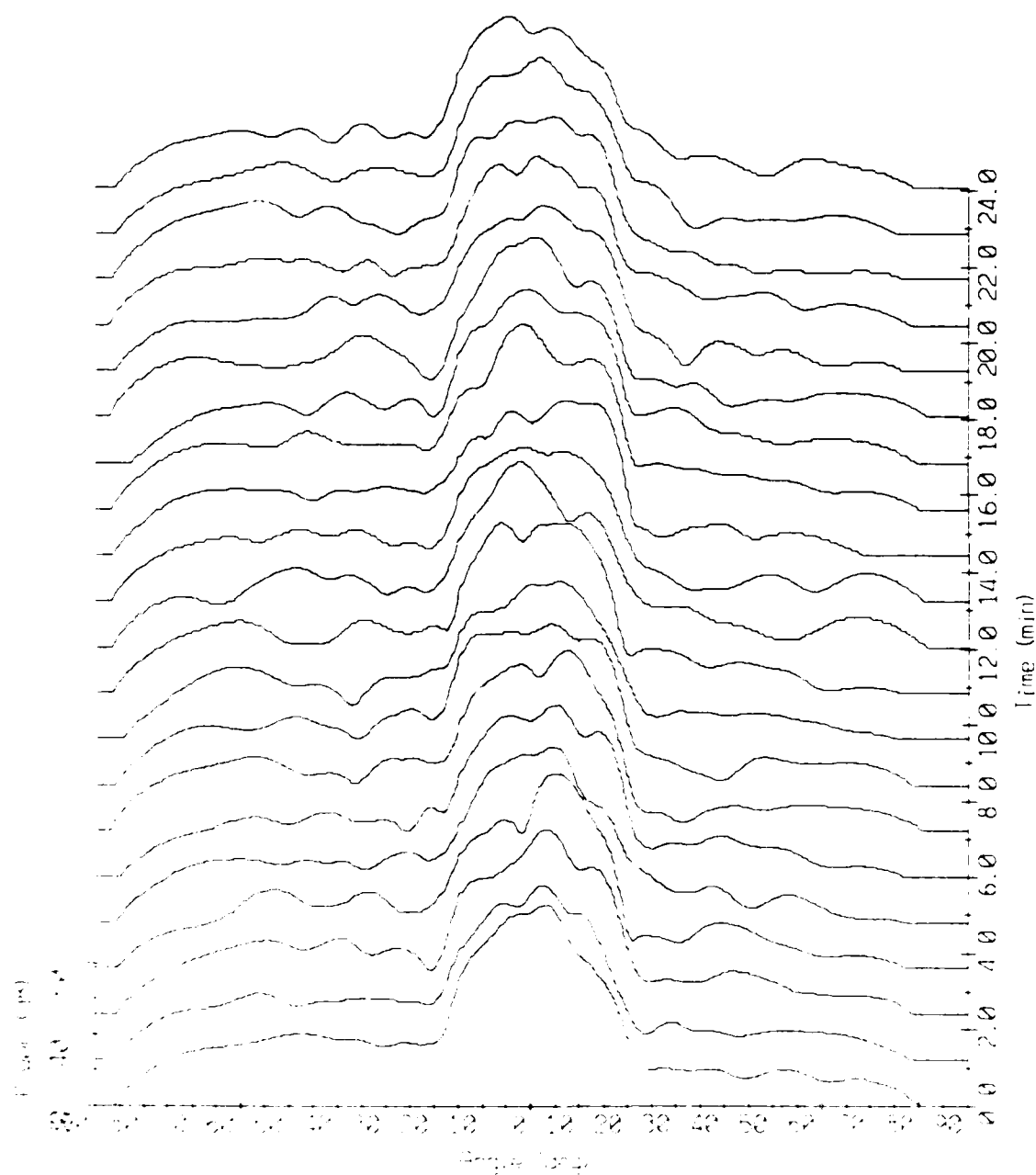
Array Response - 85010 Bin #5225
 $f = 125$ Hz, KB window ($\alpha = 1.5$)



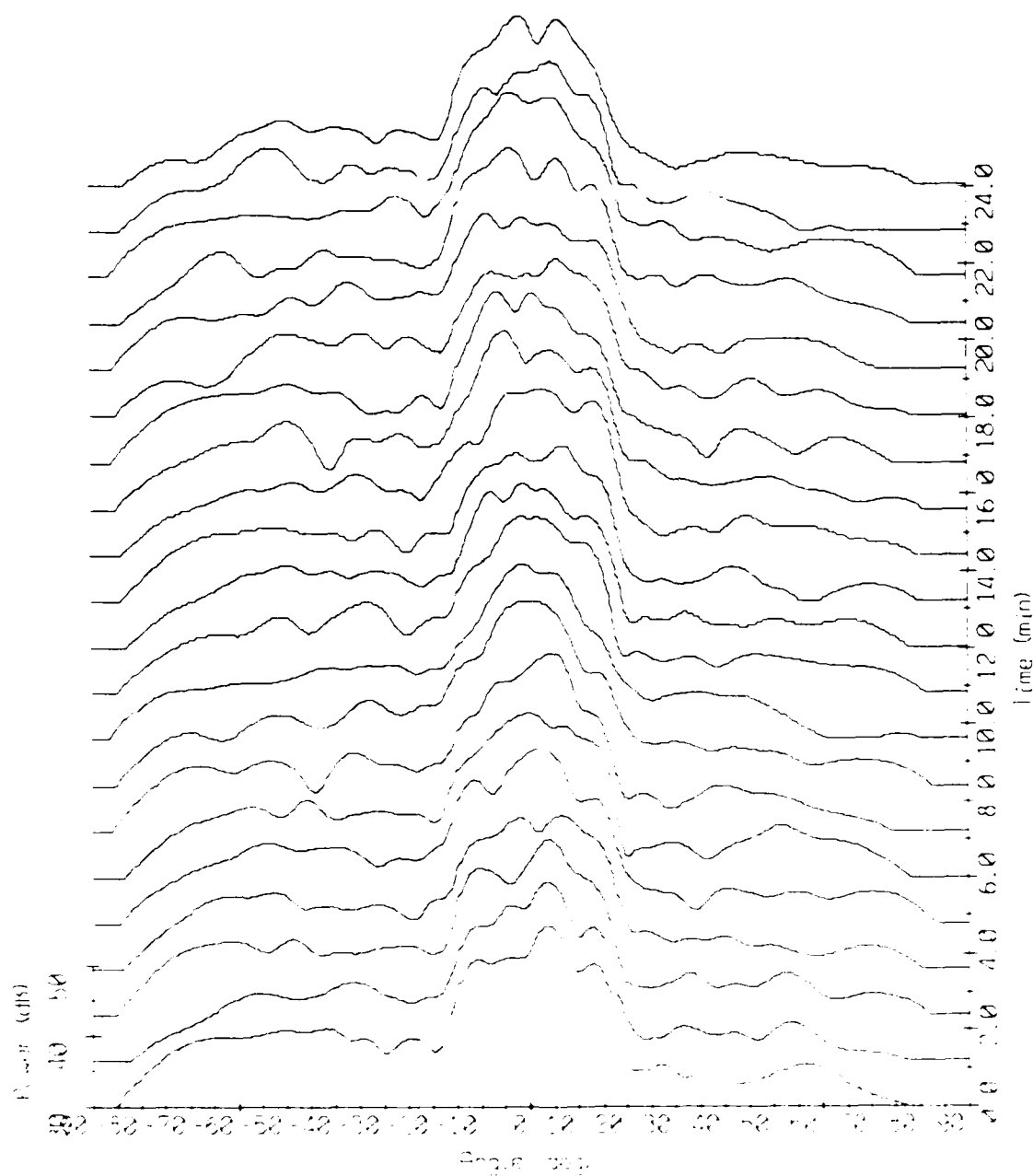
Array Response - 85010 Bin #5451
 $f = 150$ Hz, KB window ($\alpha = 1.5$)



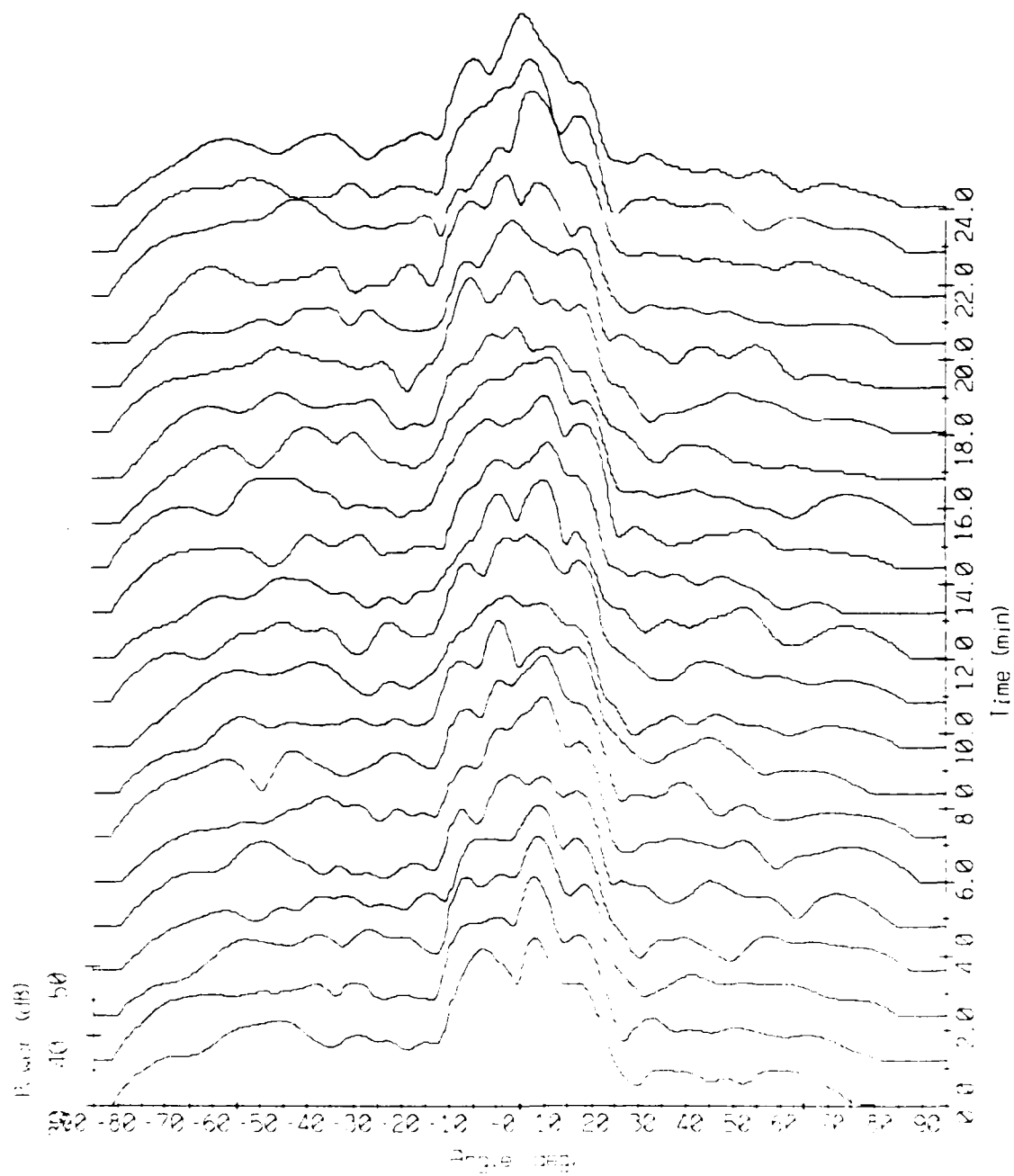
Array Response - 85010 Bin #5676
 $f = 175$ Hz, KB window ($\alpha = 1.5$)



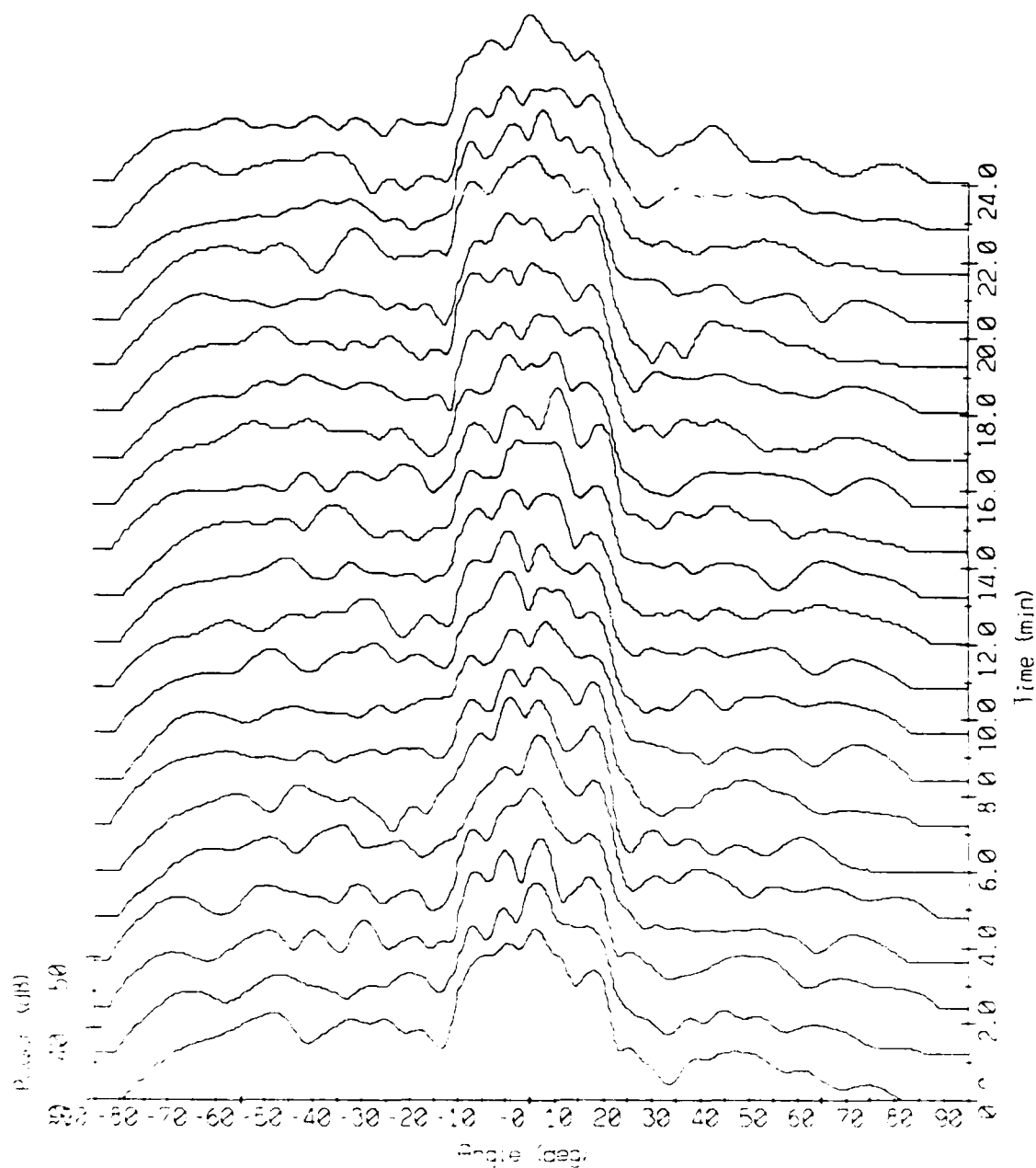
Array Response - 85010 Bin #5902
 $f = 200$ Hz, KB window ($\alpha = 1.5$)



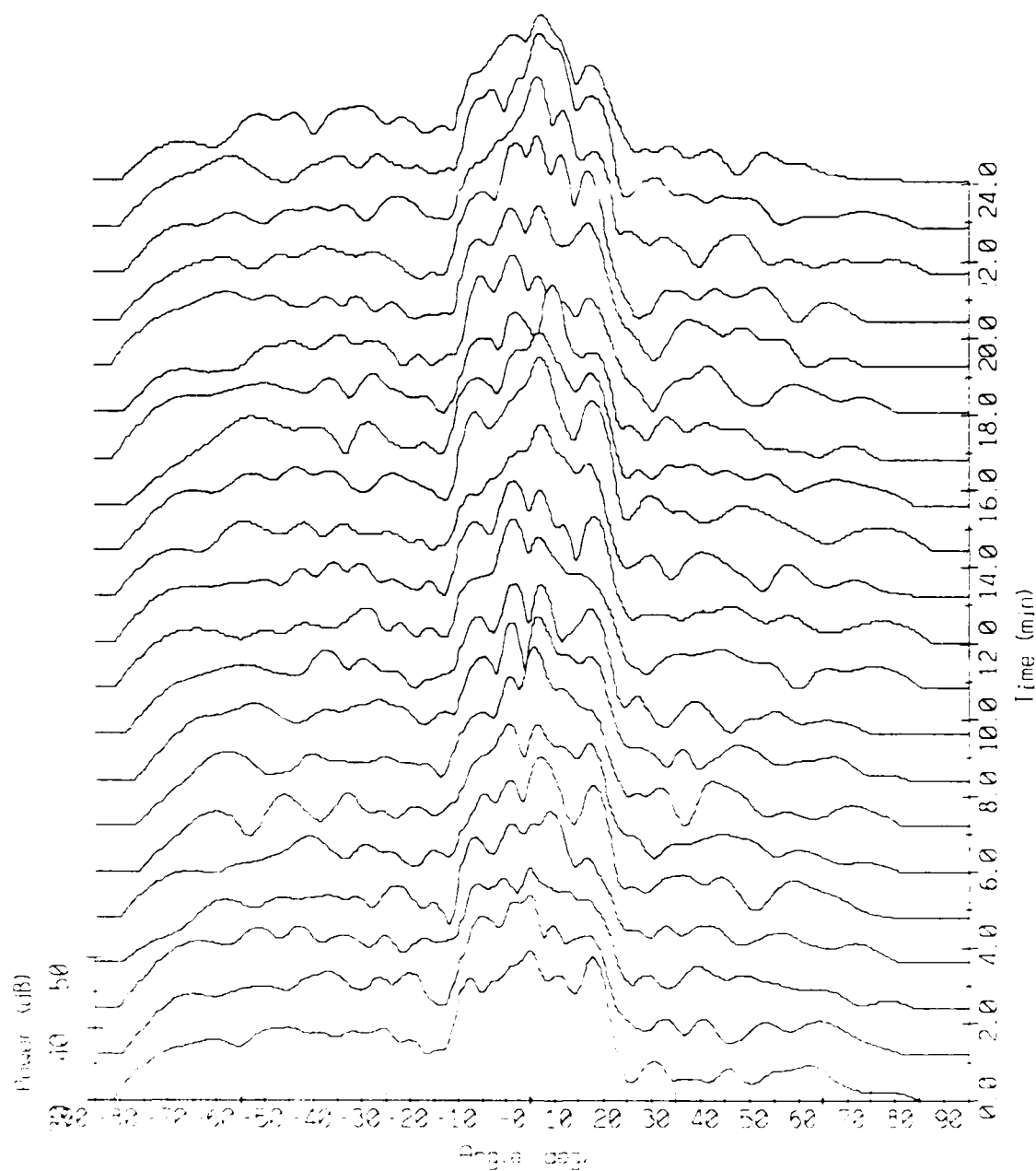
Array Response - 85010 Bin #6127
 $f = 225$ Hz, KB window ($\alpha = 1.5$)



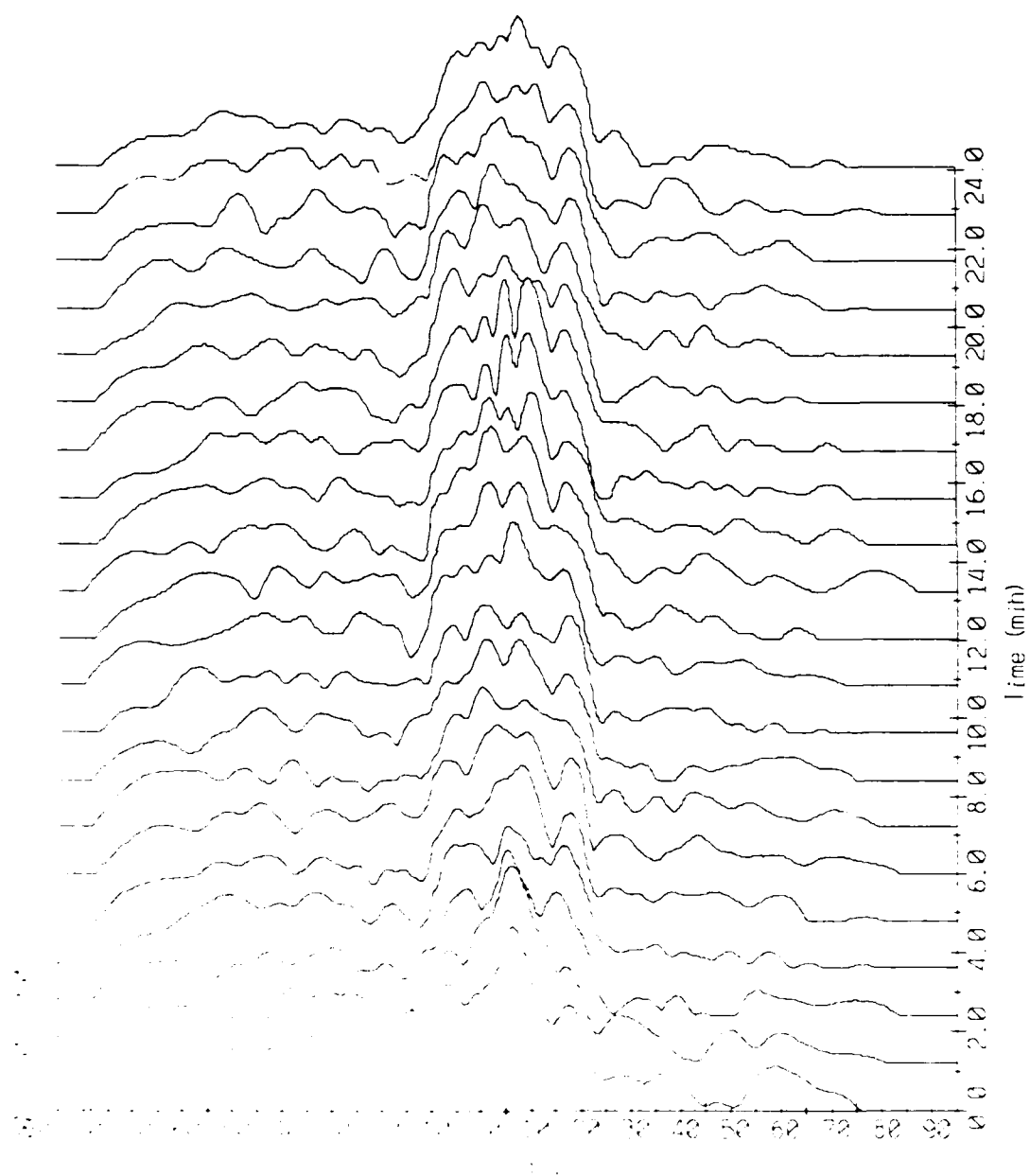
Array Response - 85010 Bin #6354
 $f = 250$ Hz, KB window ($\alpha = 1.5$)



Array Response - 85010 Bin #6579
 $f = 275$ Hz, KB window ($\alpha = 1.5$)

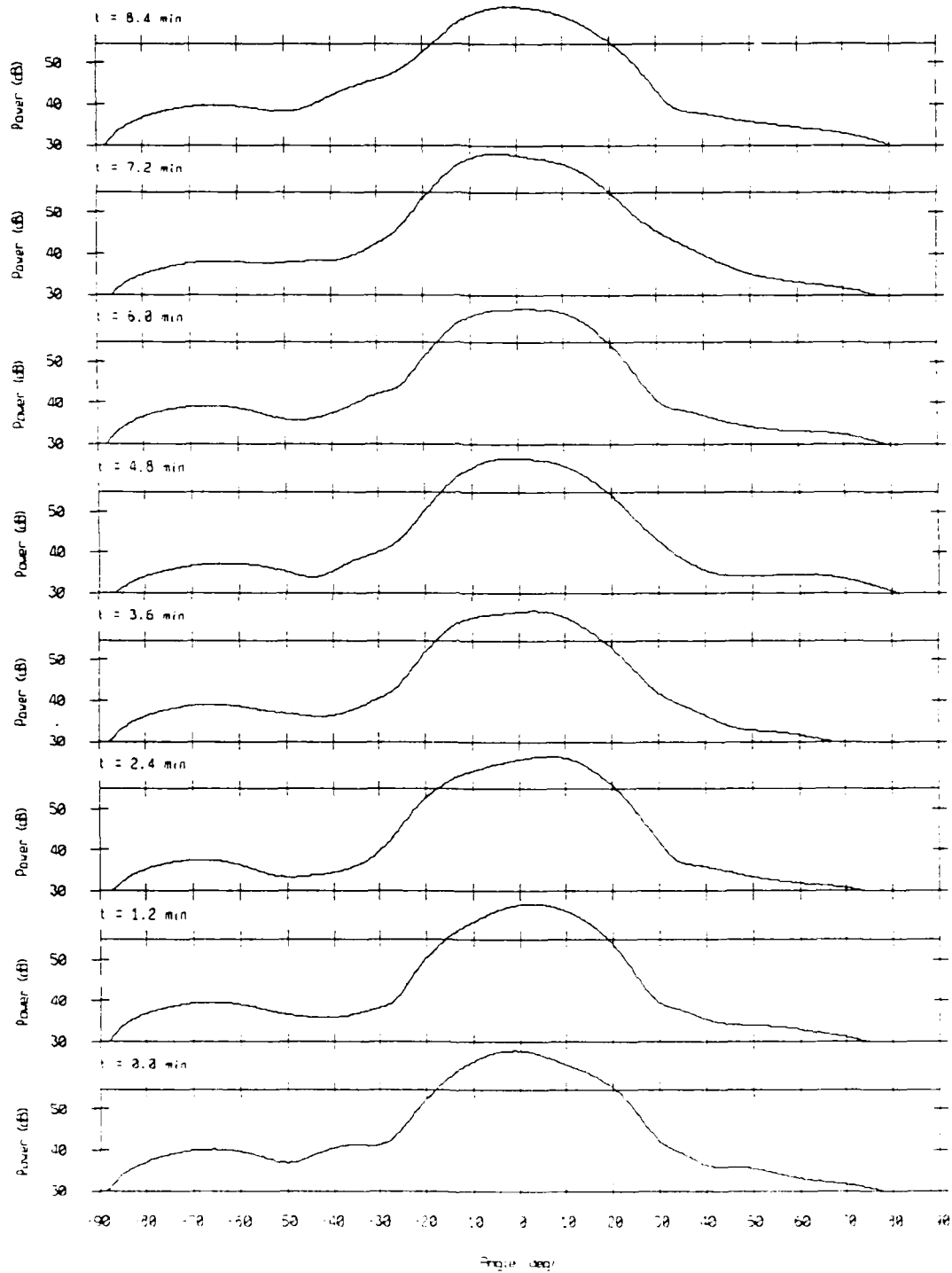


Array Response - 85010 Bin #6804
 $f = 300$ Hz, KB window ($\alpha = 1.5$)



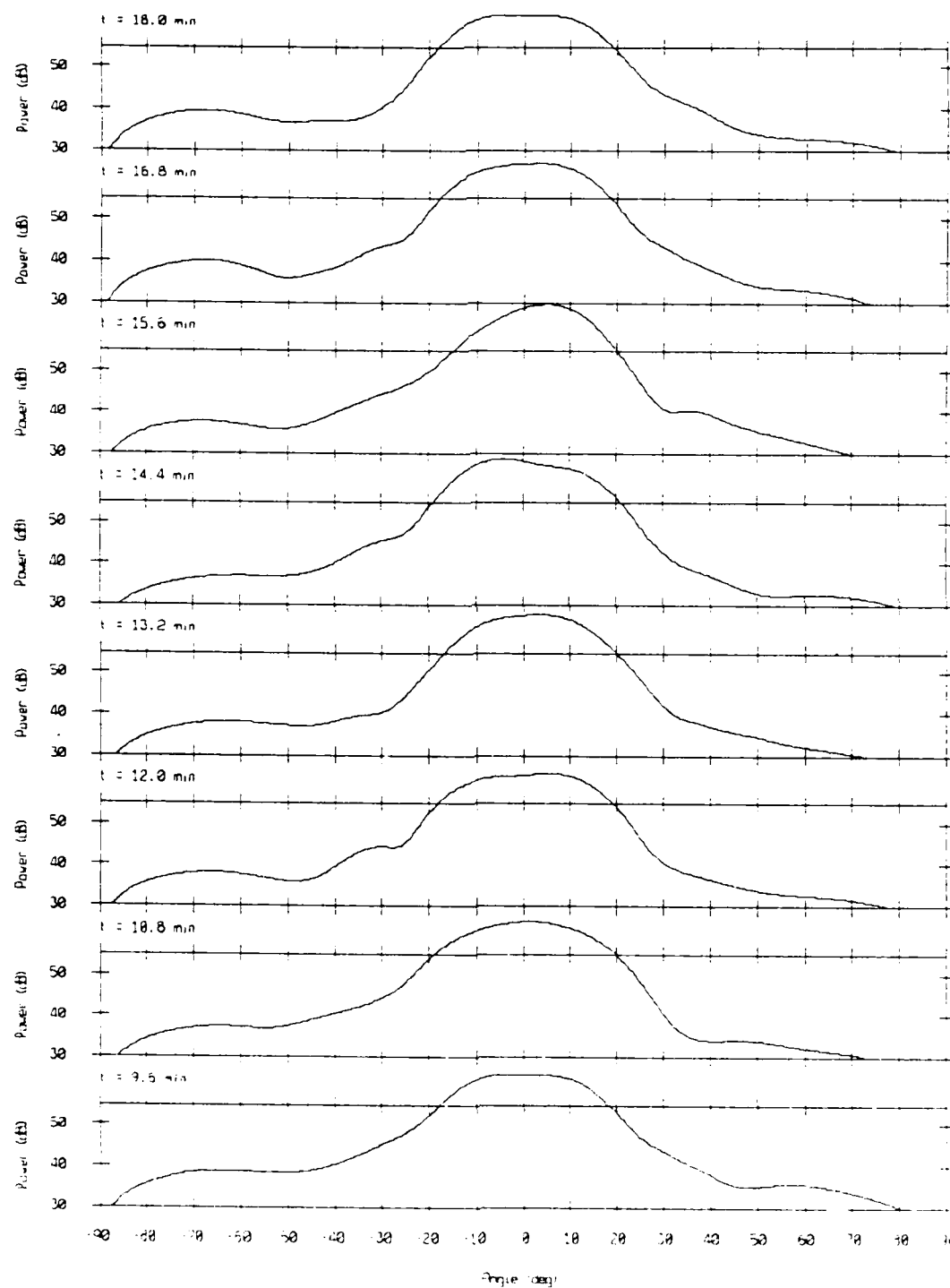
Array Response - 85010 Bin #4774

$f = 75$ Hz, KB window ($\alpha = 1.5$)



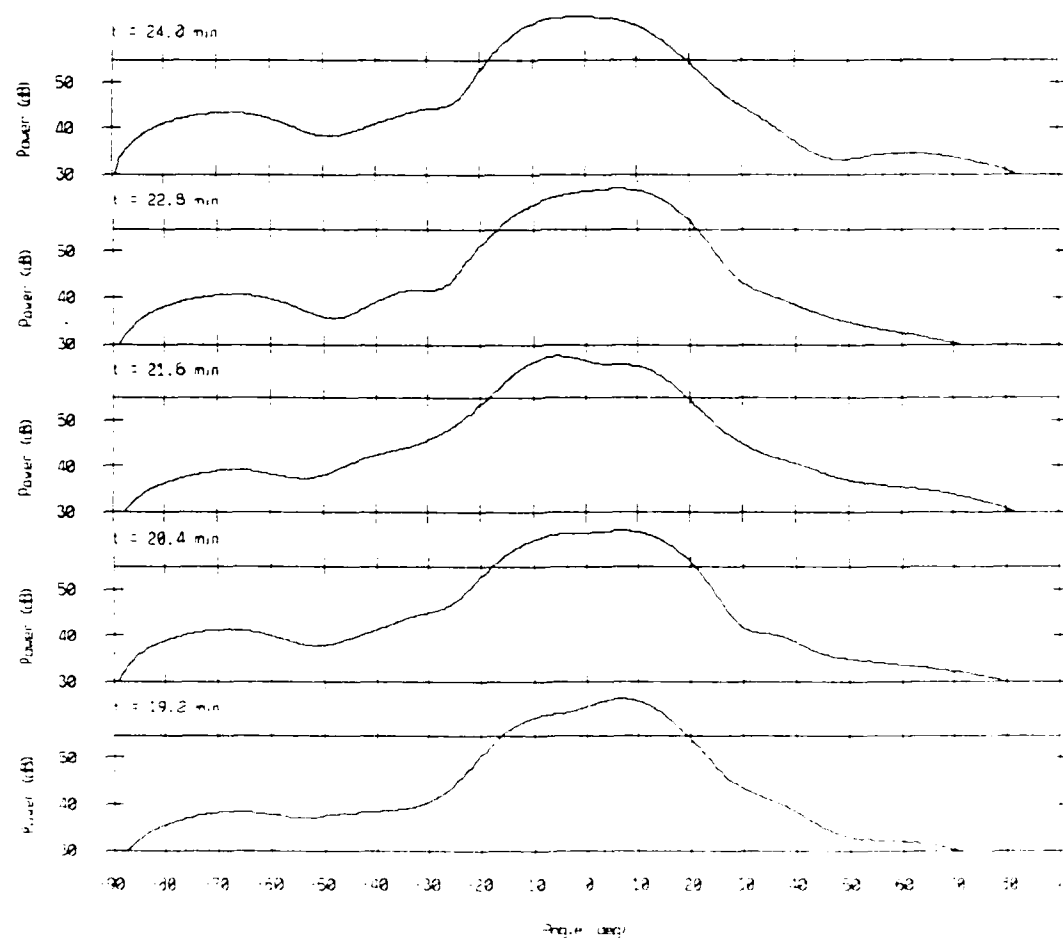
Array Response - 85010 Bin #4774

$f = 75$ Hz, KB window ($\alpha = 1.5$)



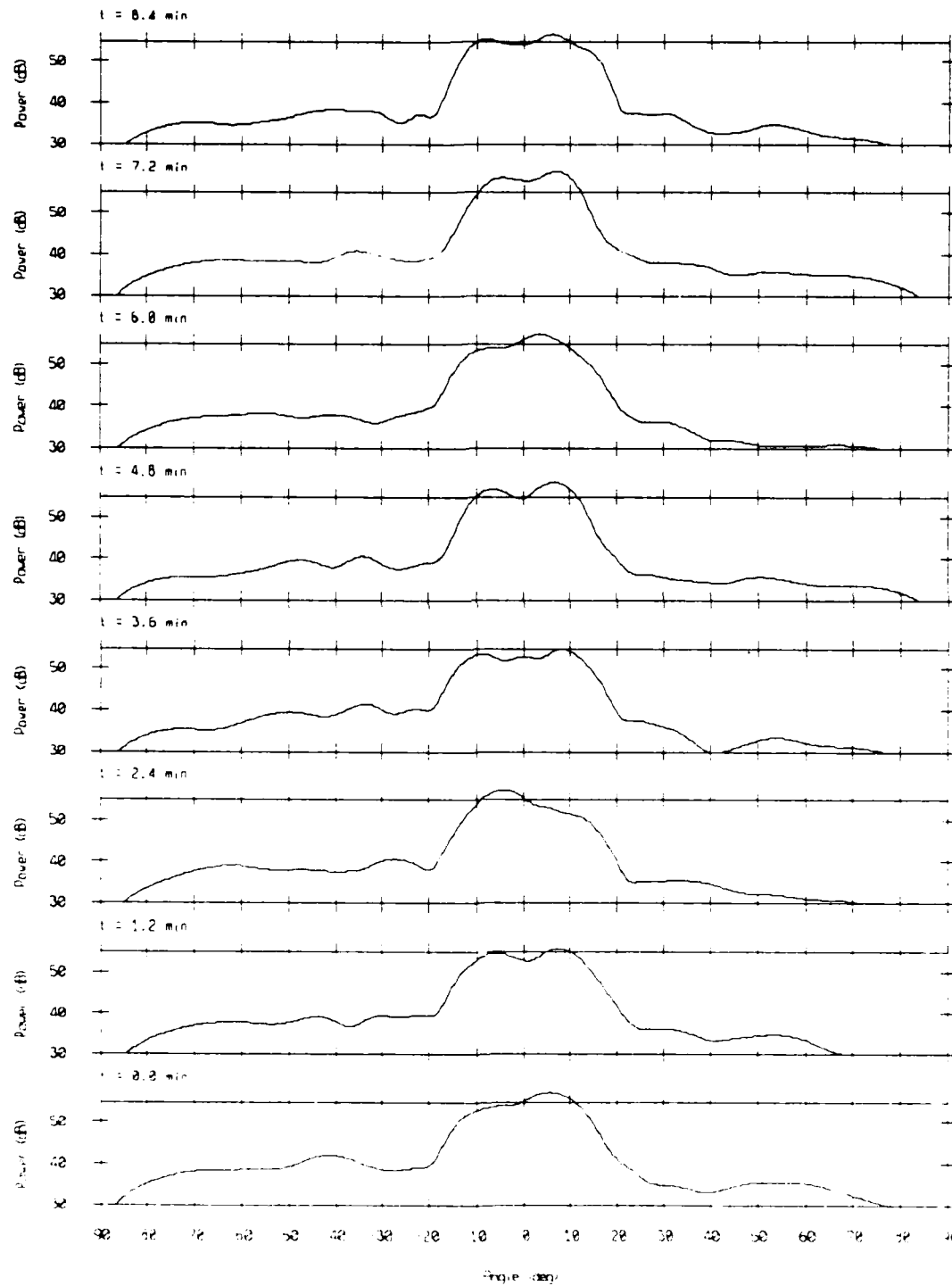
Array Response - 85010 Bin #4774

$f = 75$ Hz, KB window ($\alpha = 1.5$)



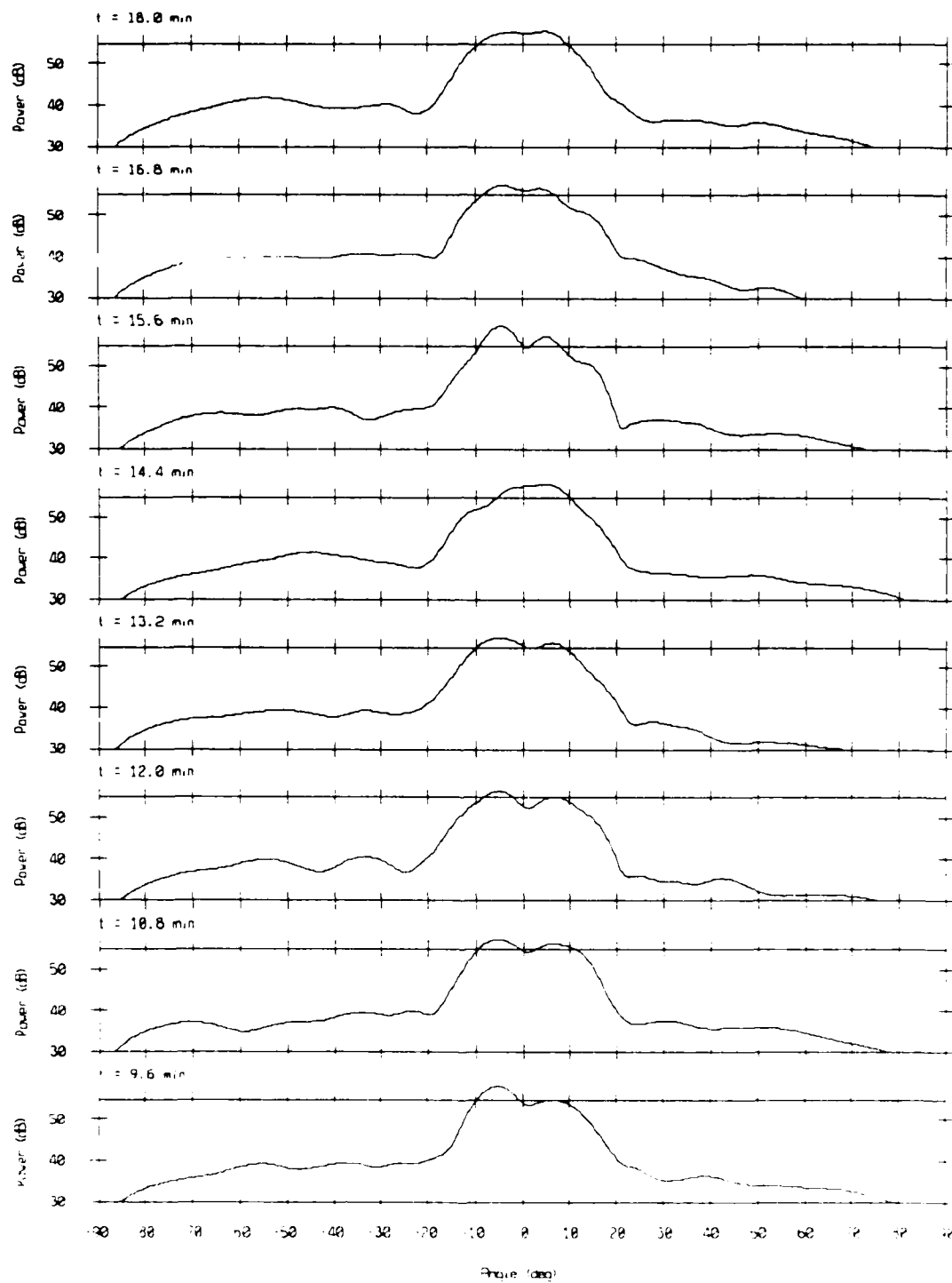
Array Response - 85010 Bin #5451

$f = 150$ Hz, KB window ($\alpha = 1.5$)



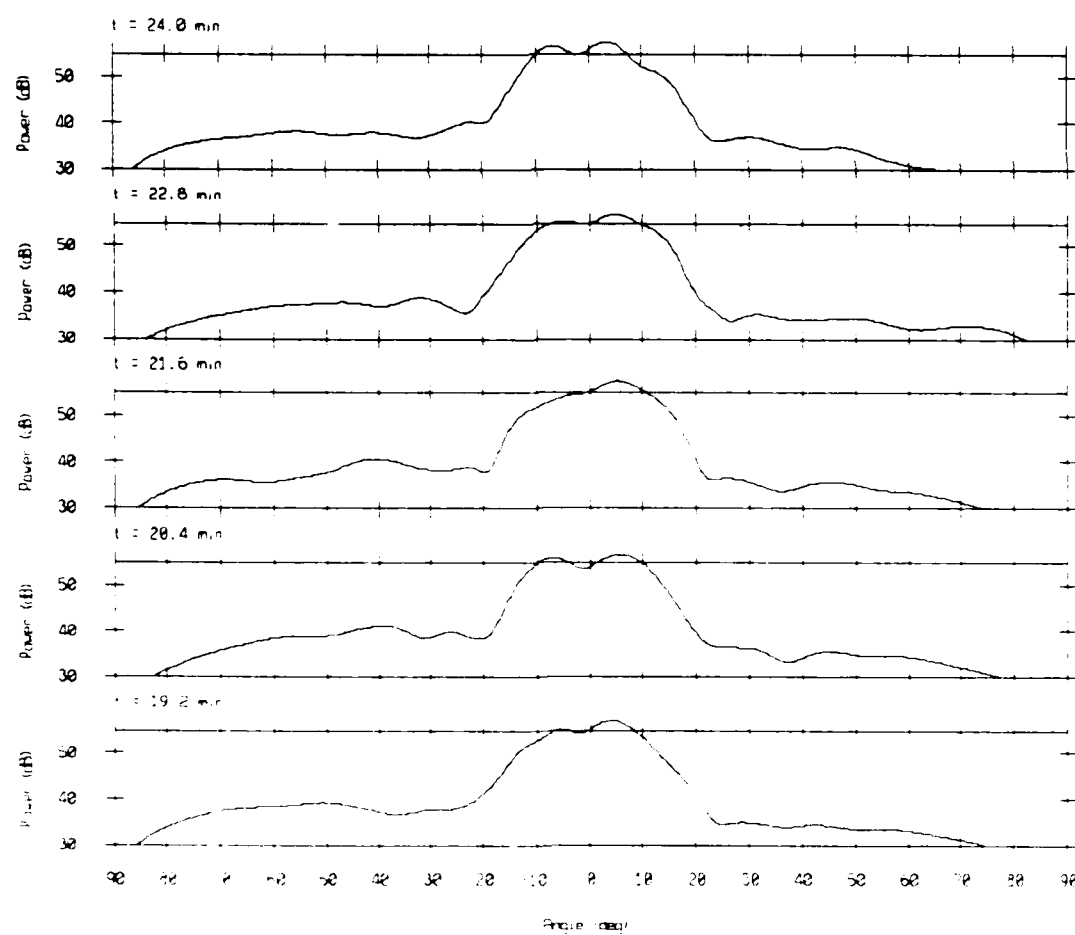
Array Response - 85010 Bin #5451

$f = 150$ Hz, KB window ($\alpha = 1.5$)

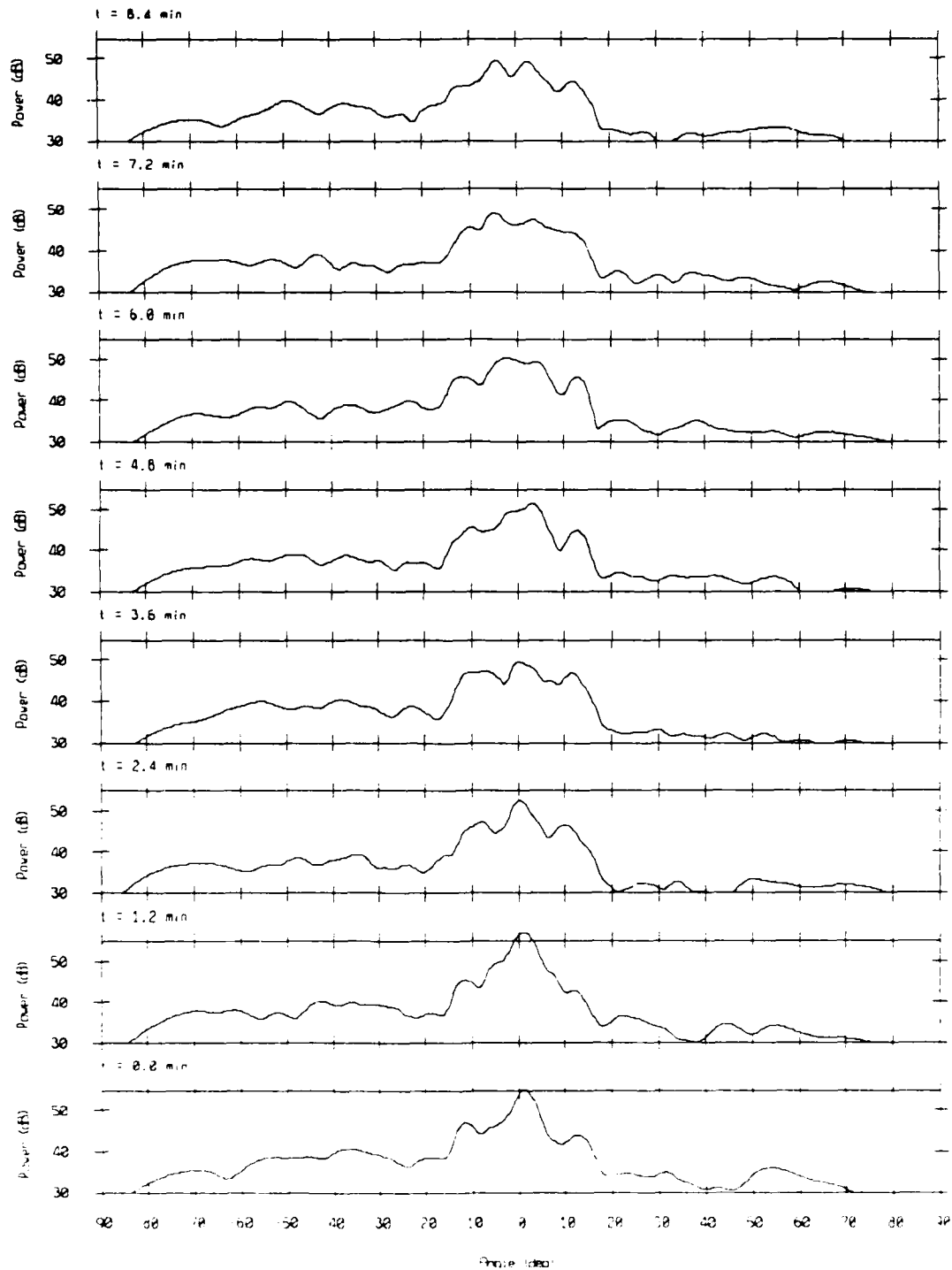


Array Response - 85010 Bin #5451

$f = 150$ Hz, KB window ($\alpha = 1.5$)

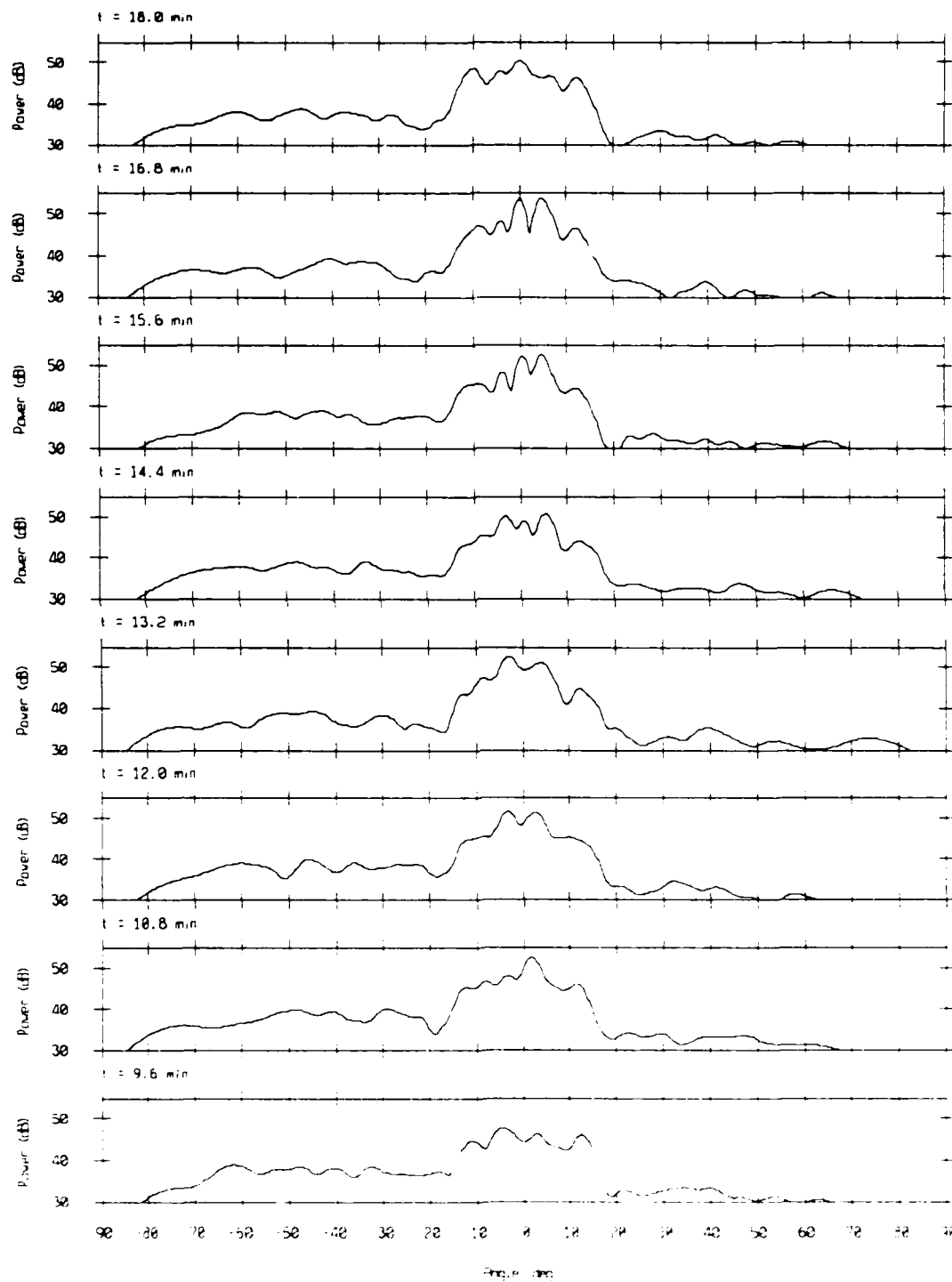


Array Response - 85010 Bin #6804
 $f = 300$ Hz, KB window ($\alpha = 1.5$)



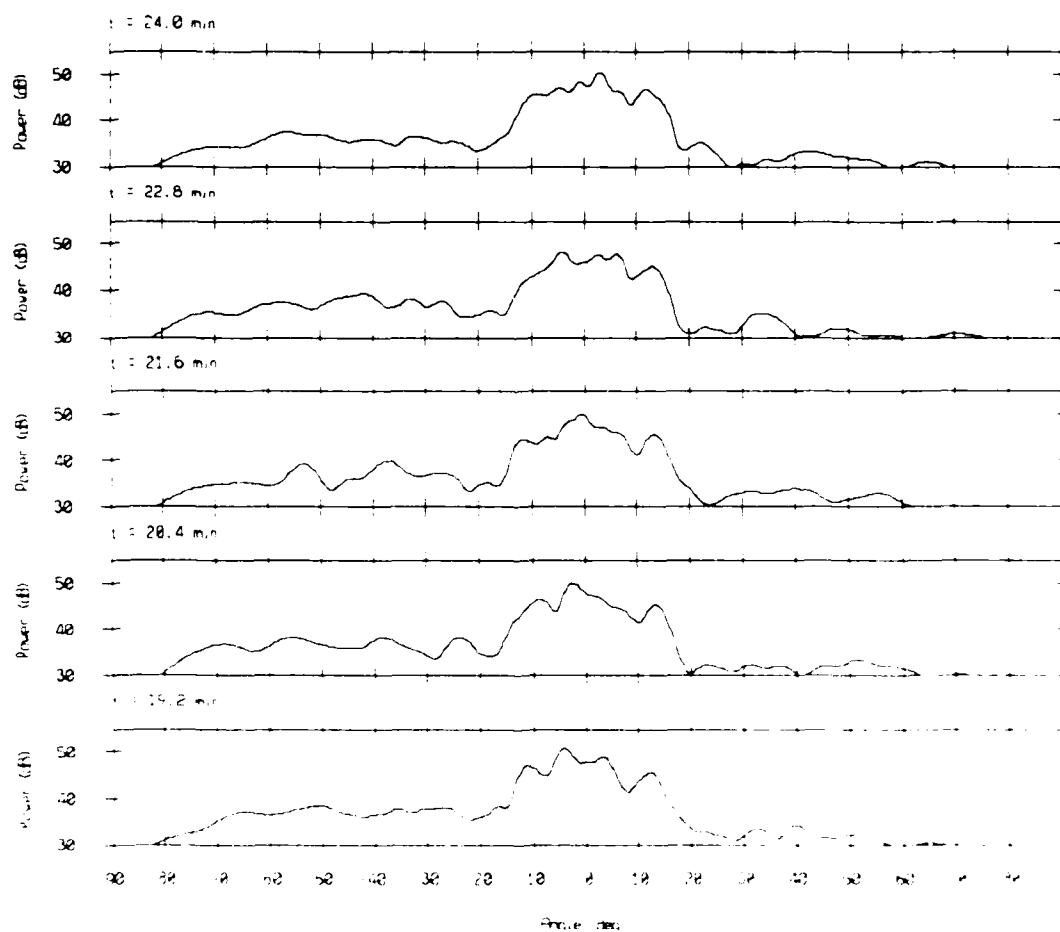
Array Response - 85010 Bin #6804

$f = 300$ Hz, KB window ($\alpha = 1.5$)



Array Response - 85010 Bin #6804

$f = 300$ Hz, KB window ($\alpha = 1.5$)



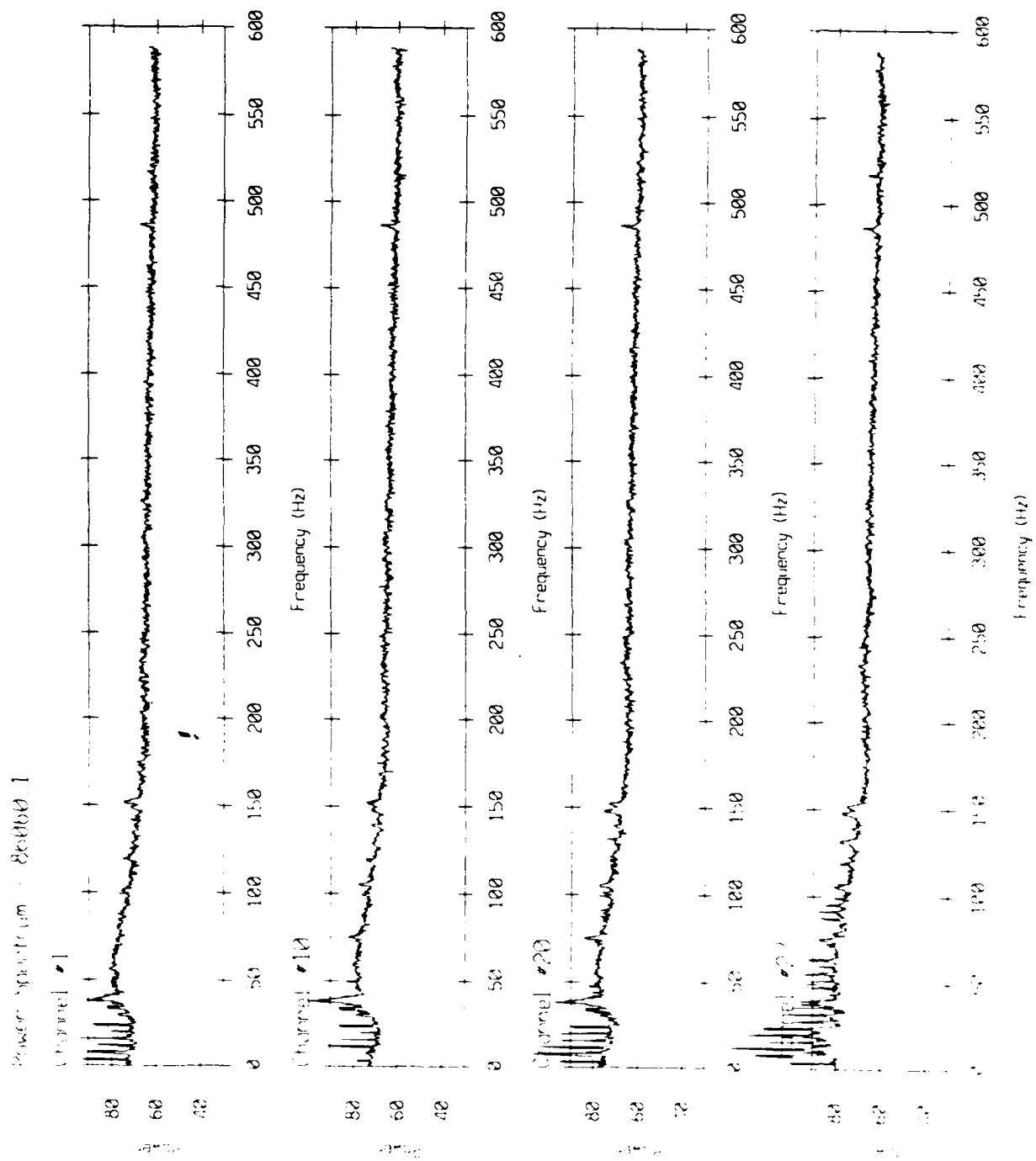


Figure 9.

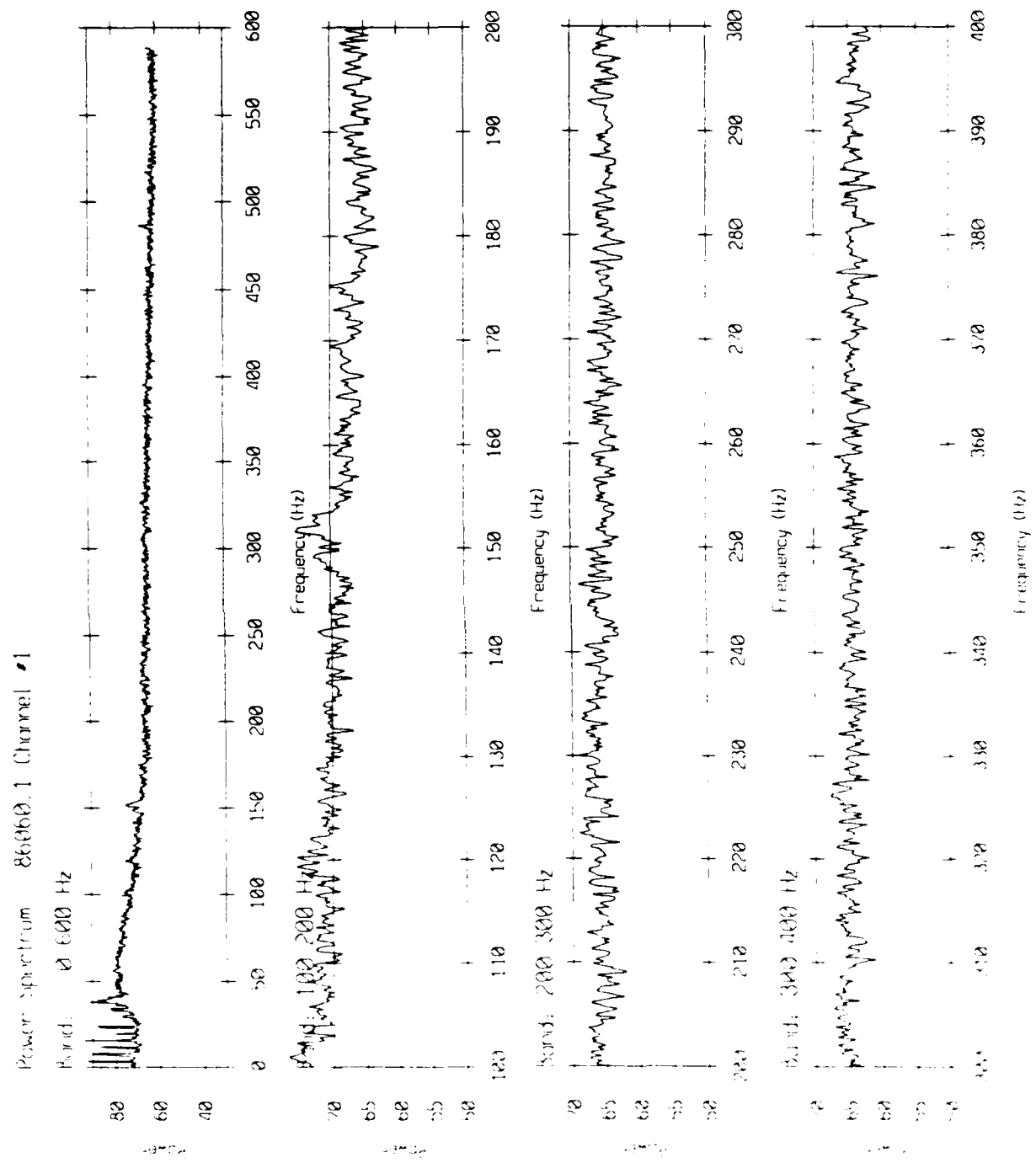


Figure 10(a).

Power Spectrum - 2000.1 (Panel 10)

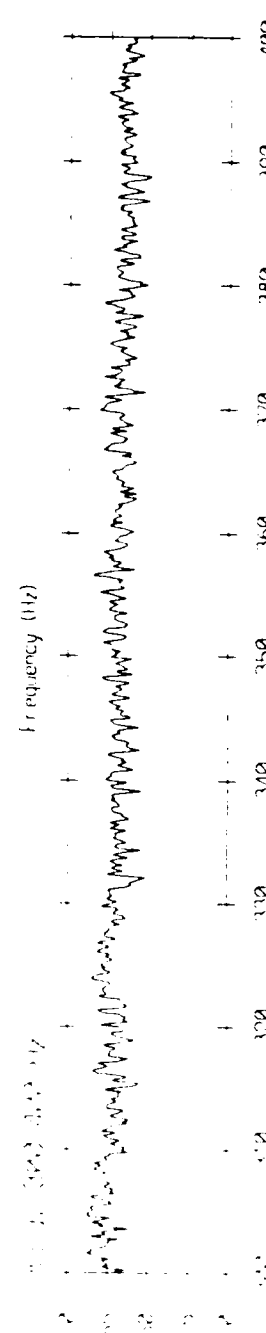
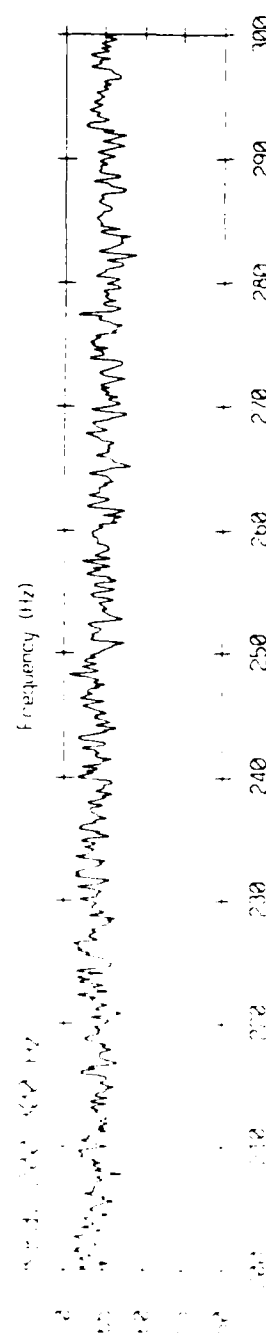
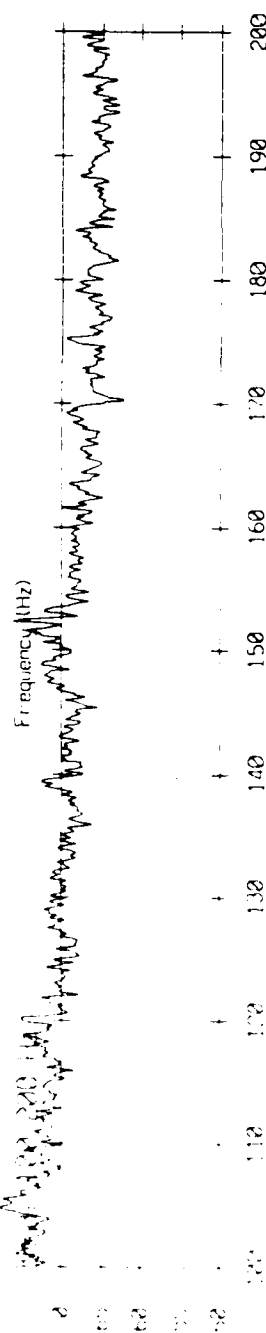
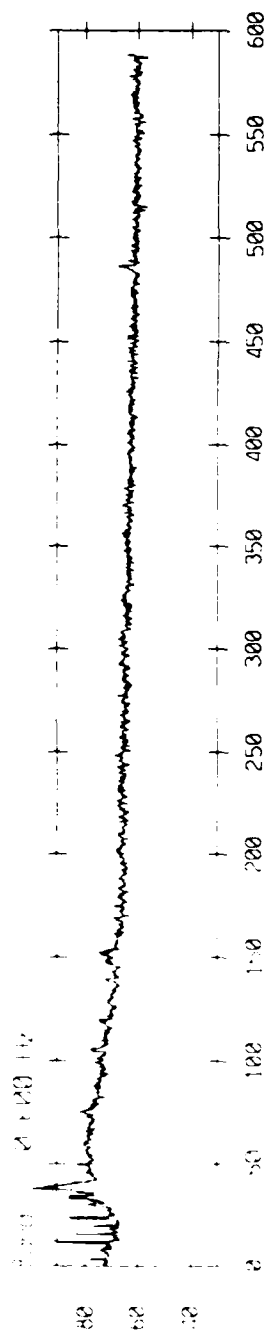


Figure 10(b).

Power Spectrum - 86060.1 Channel #20

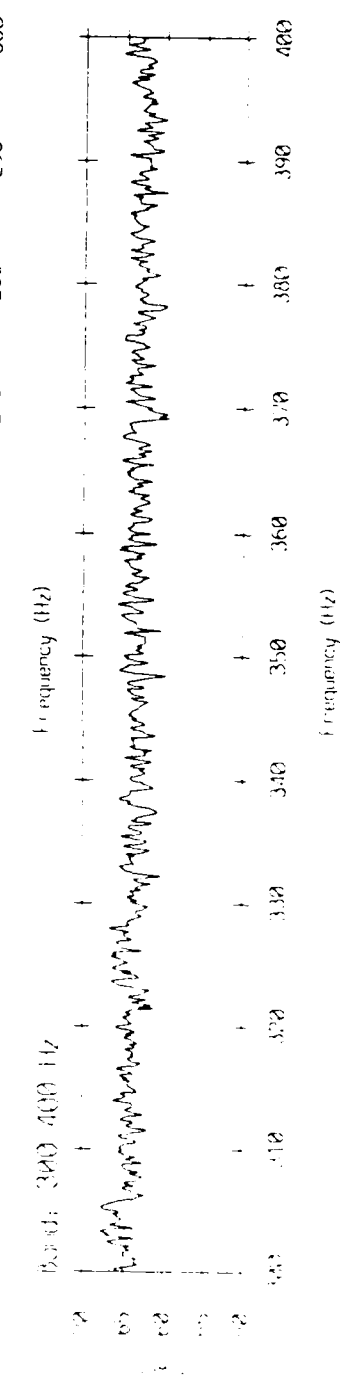
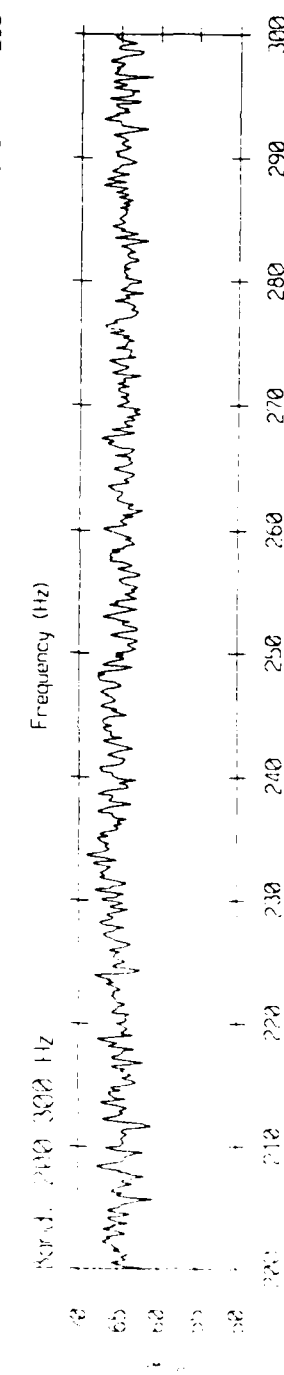
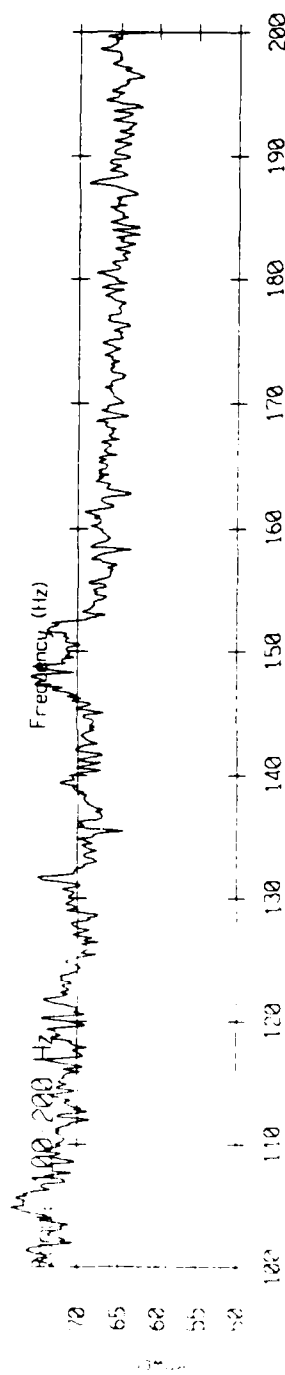
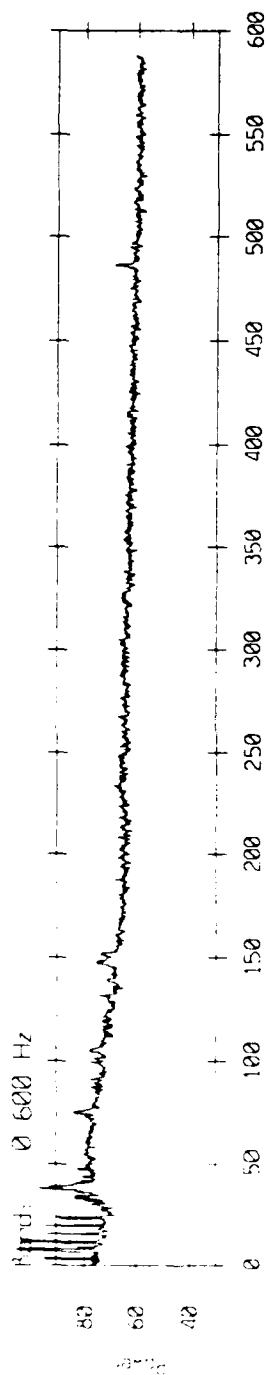


Figure 10(c).

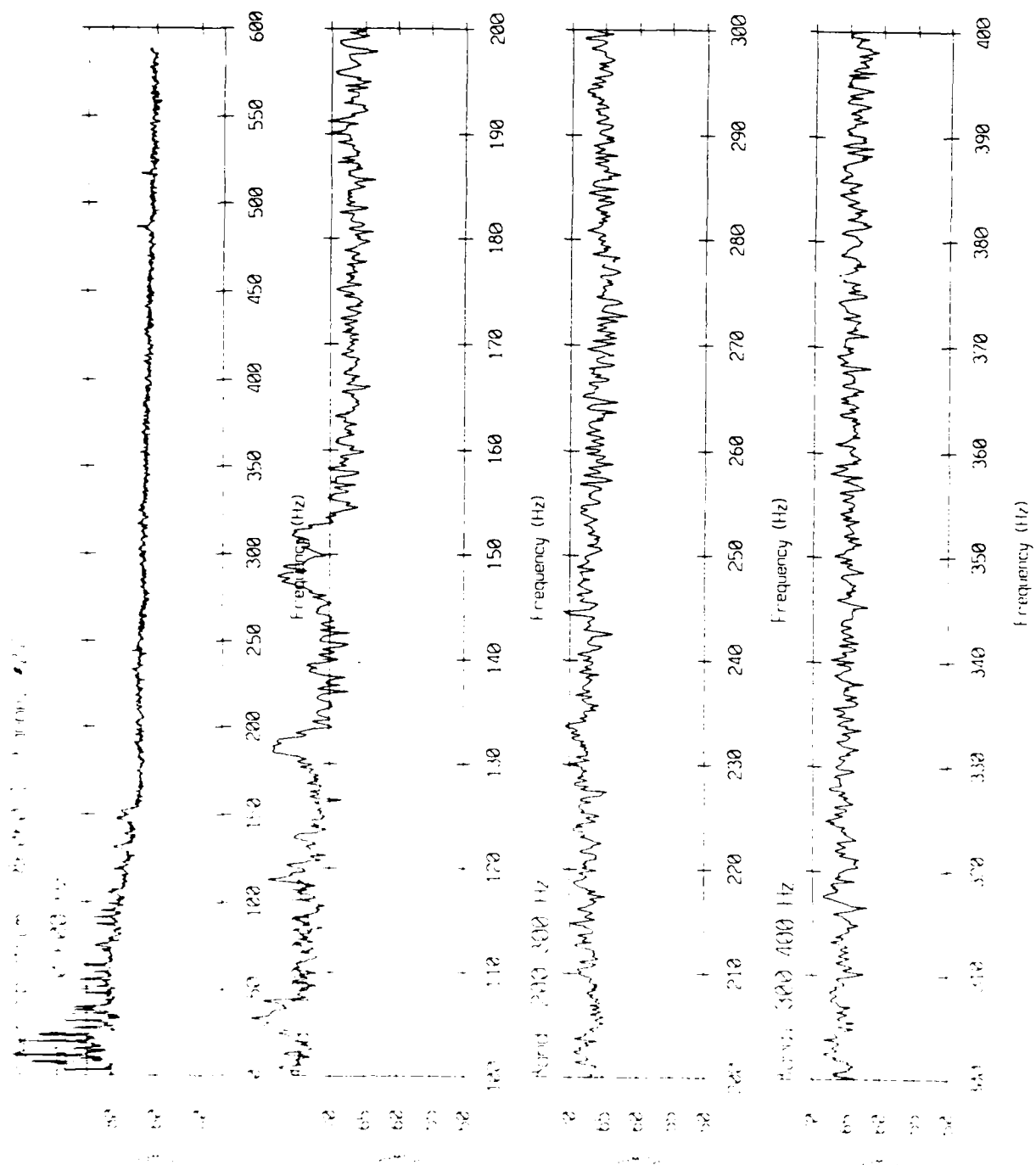
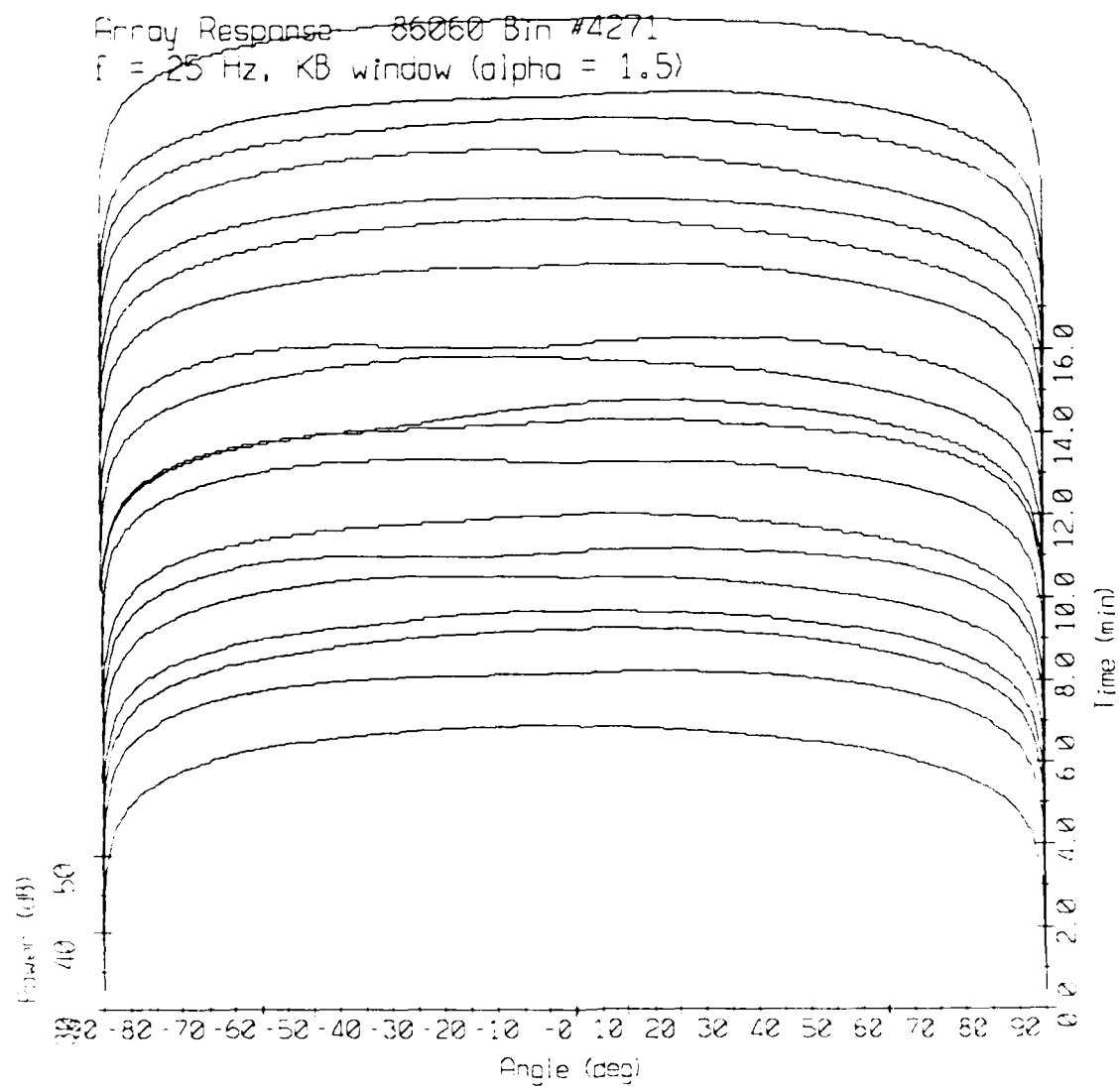
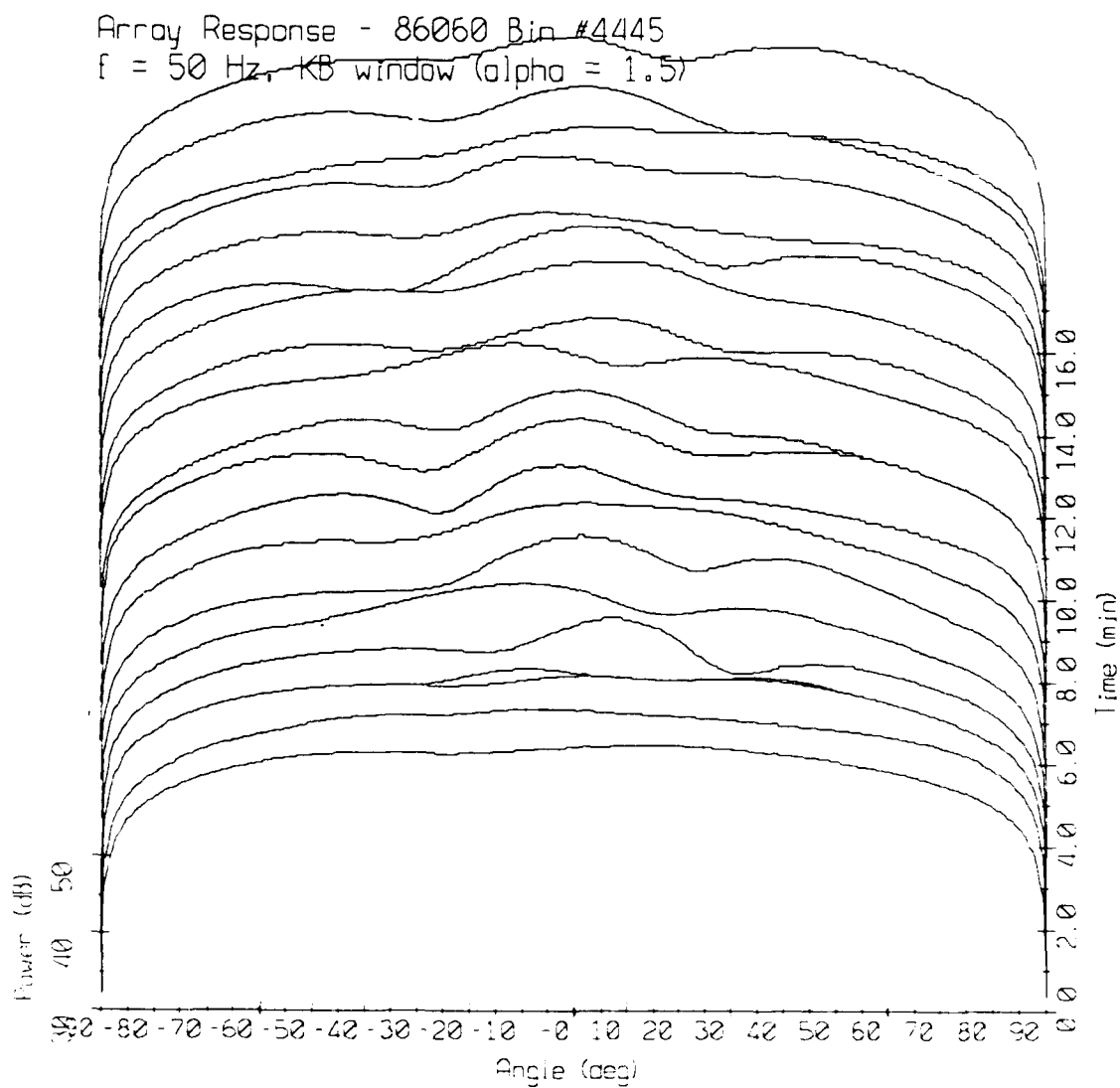
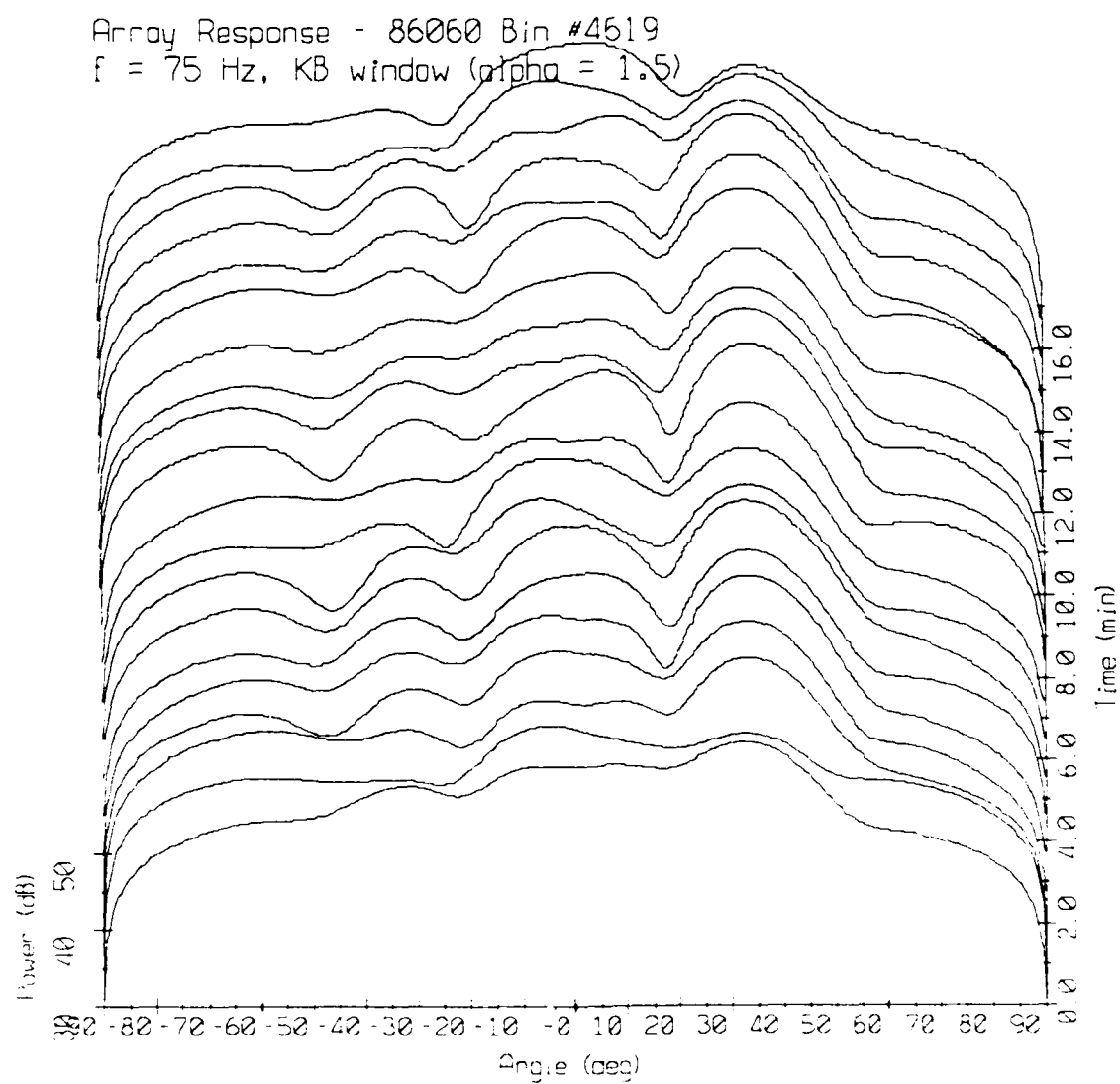
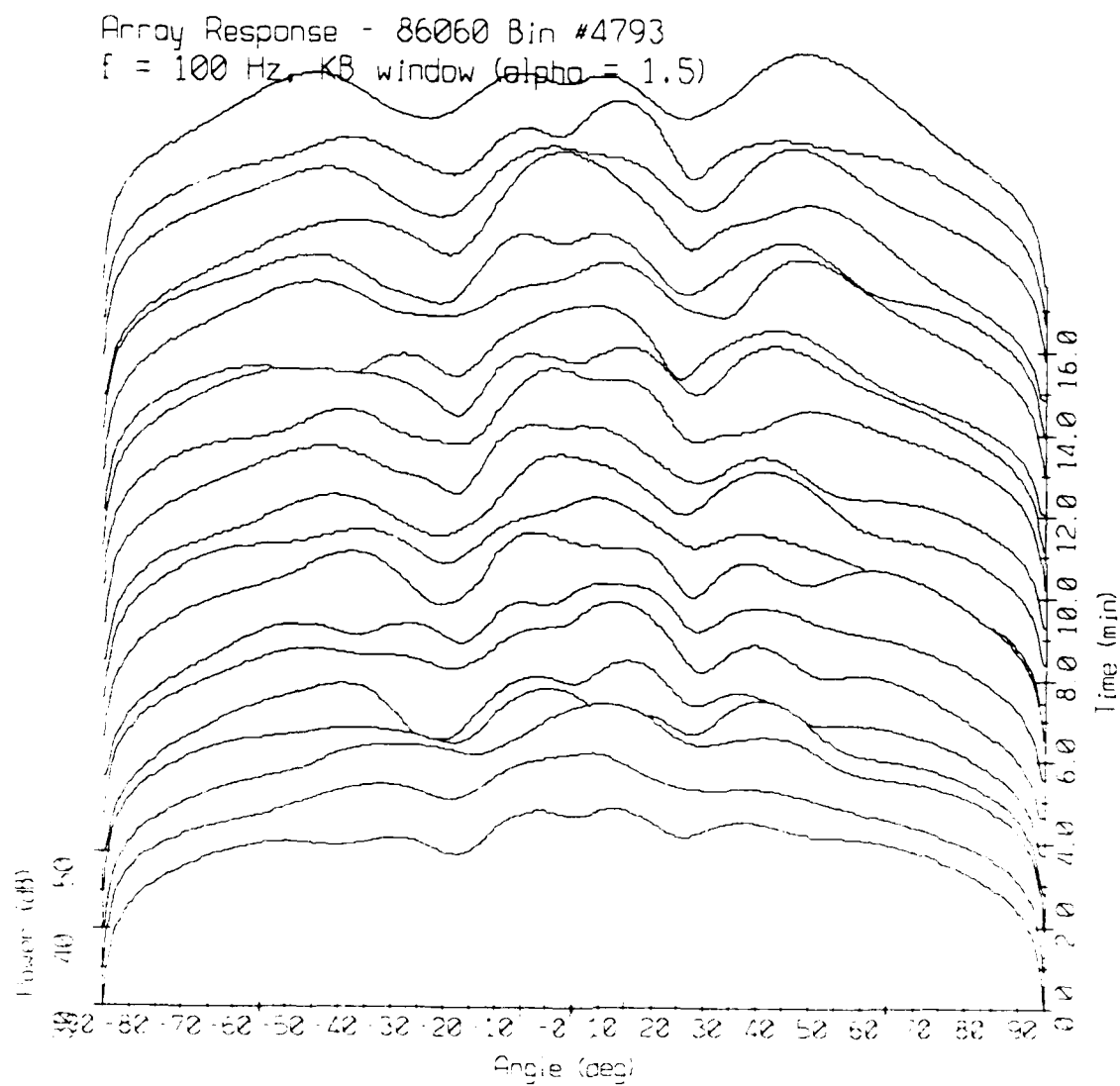


Figure 10(d).

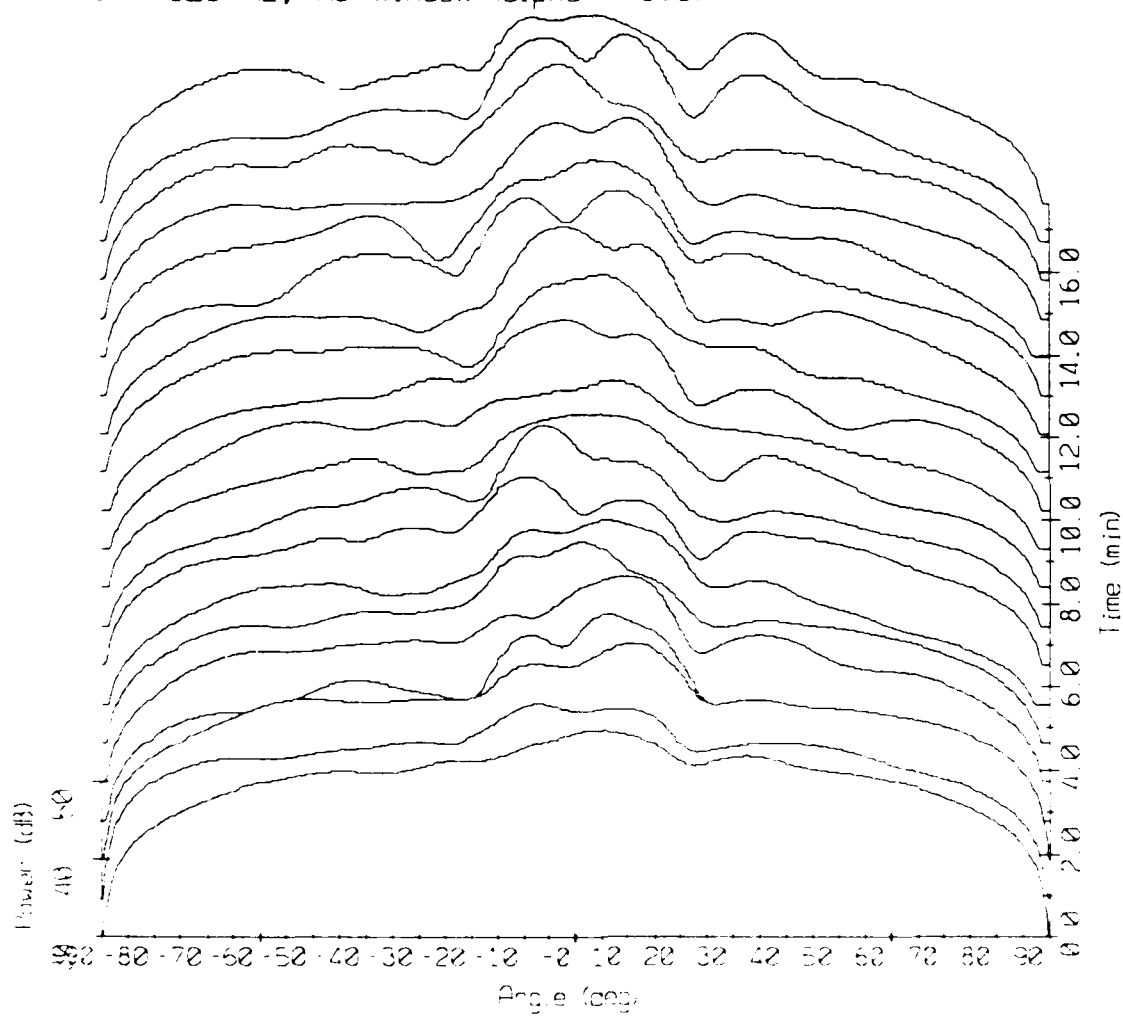




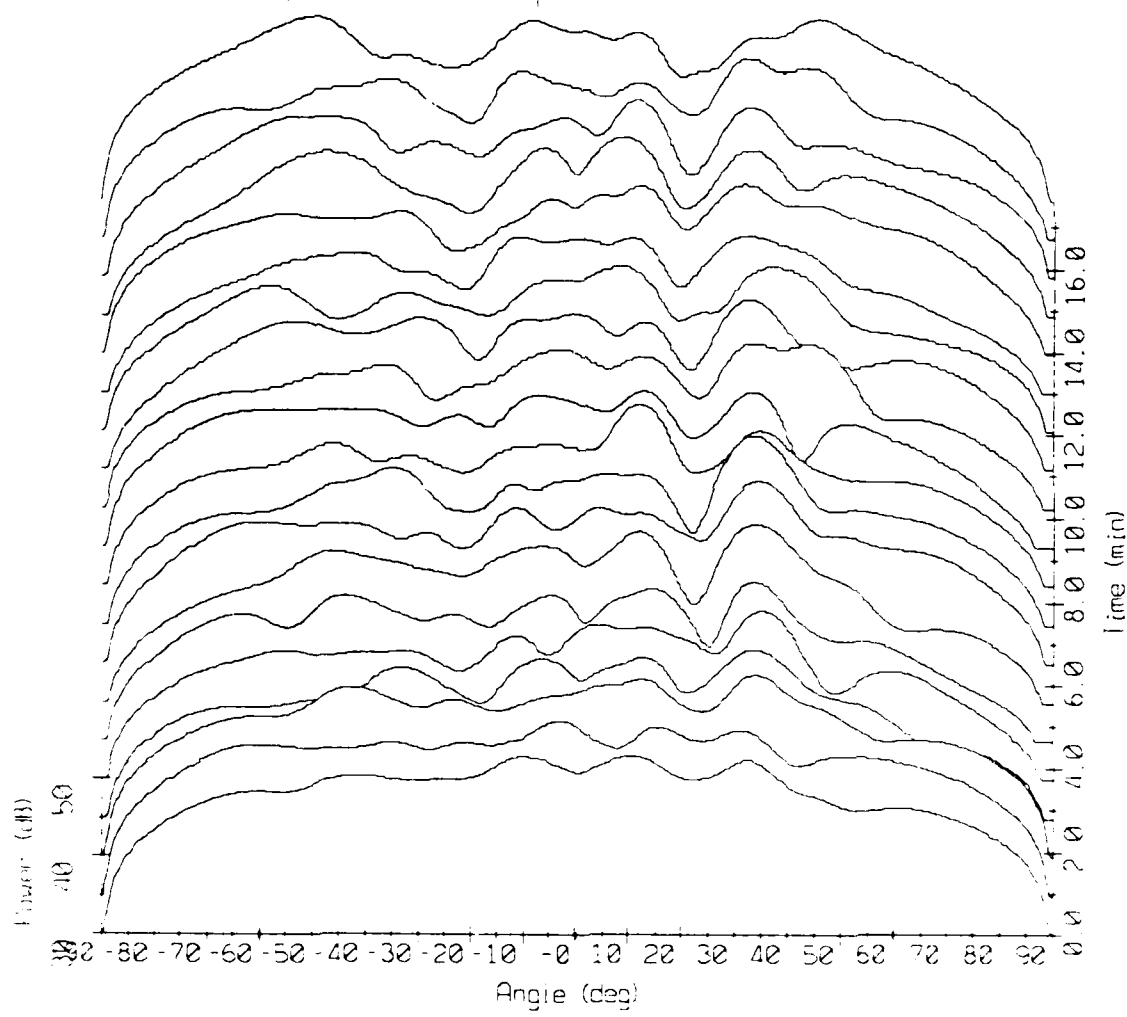




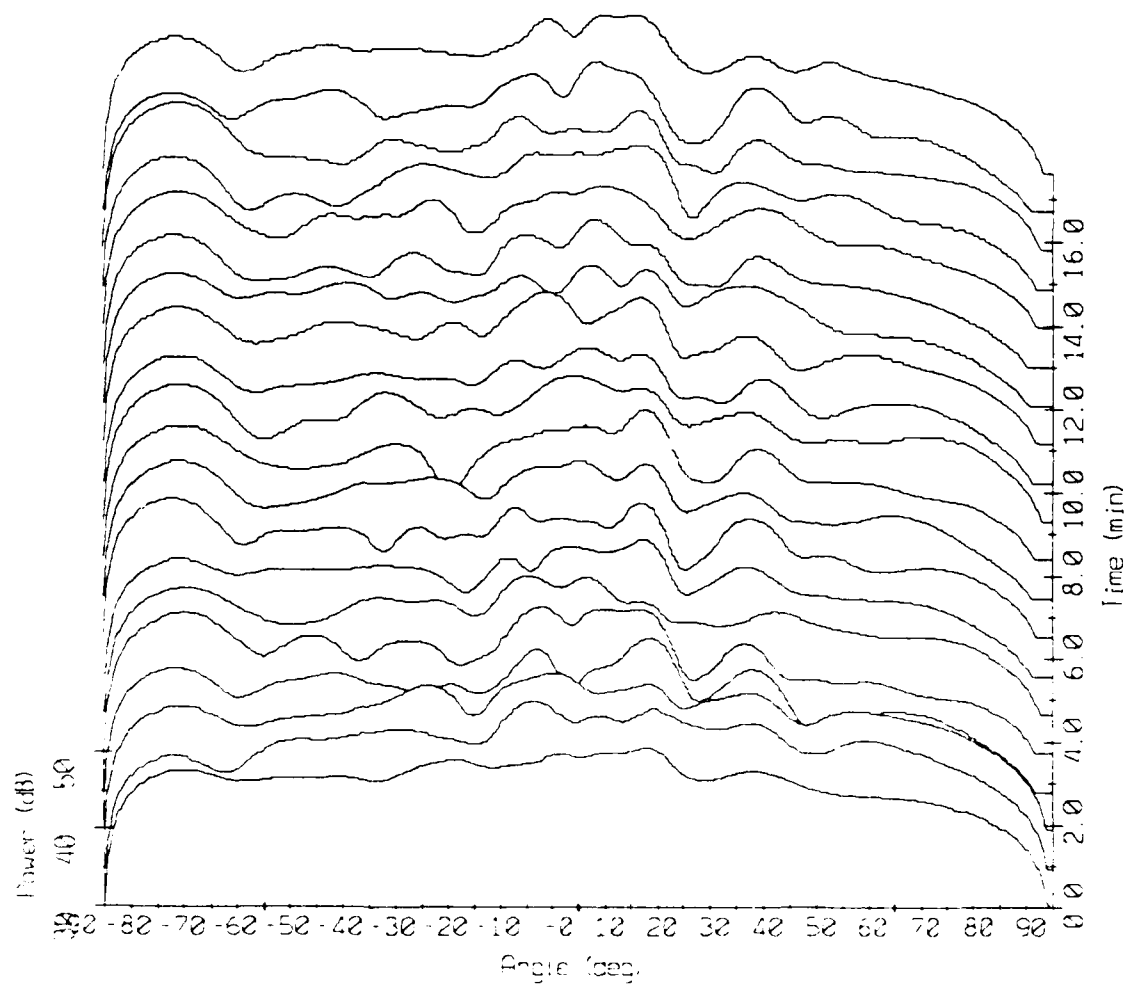
Array Response - 86060 Bin #4967
 $f = 125$ Hz, KB window ($\alpha = 1.5$)



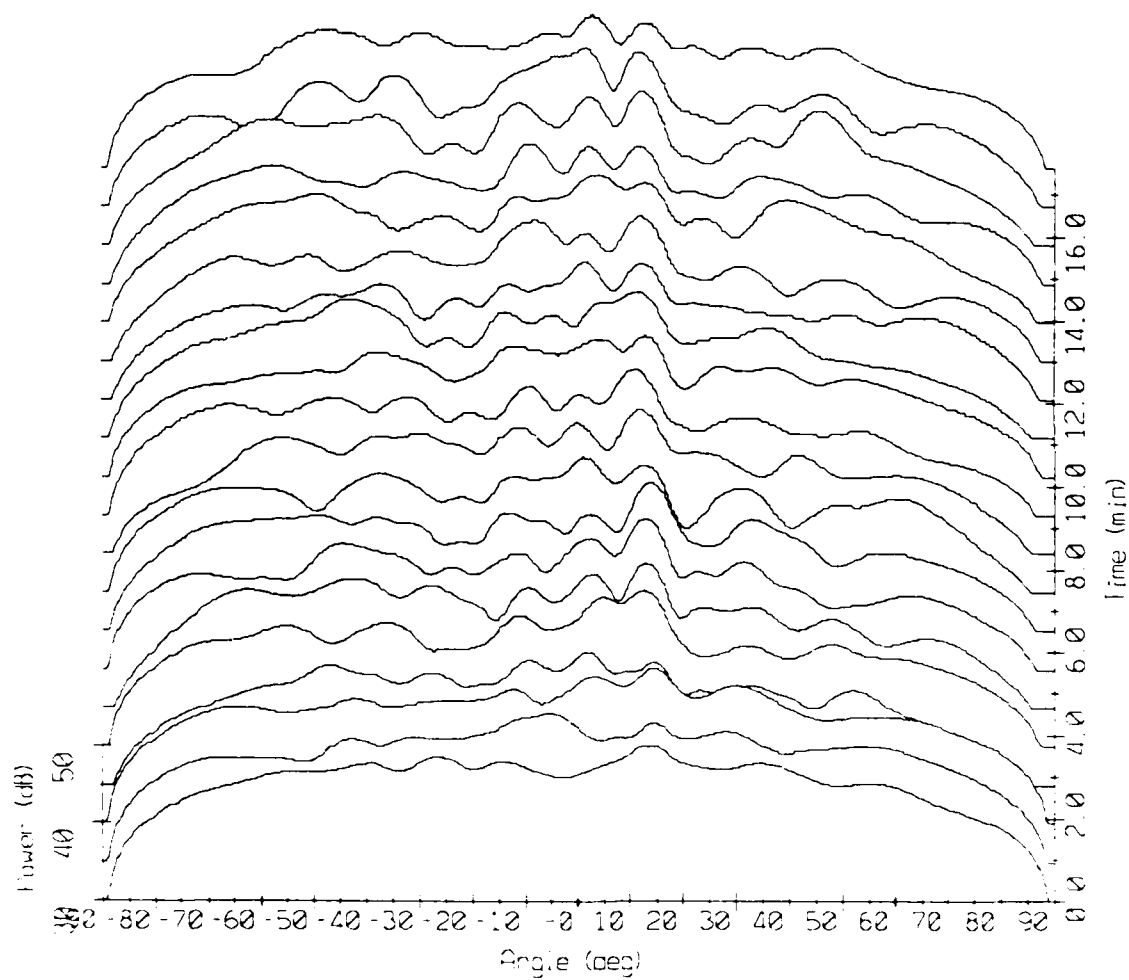
Array Response - 86060 Bin #5141
 $f = 150$ Hz, KB window ($\alpha = 1.5$)



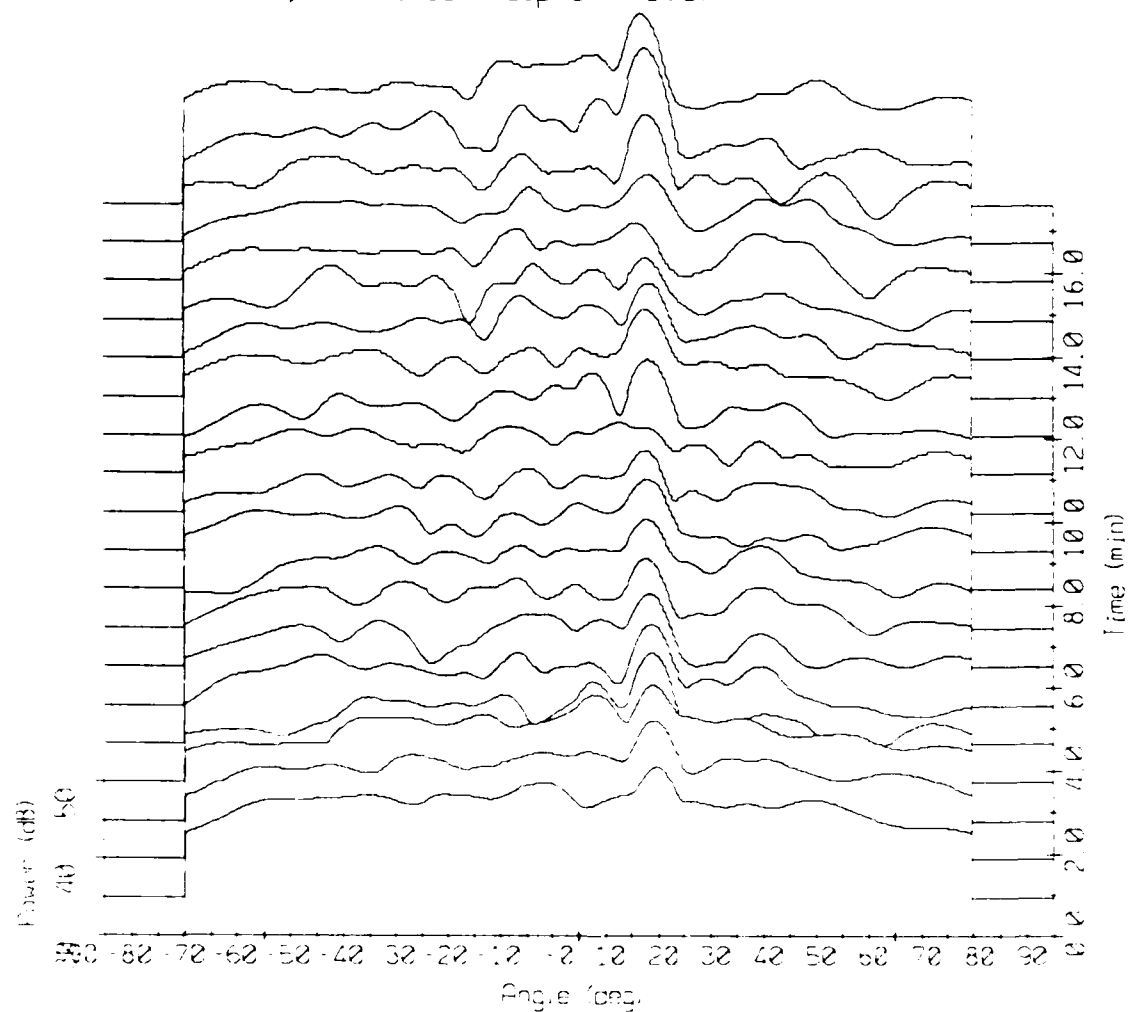
Array Response - 86060 Bin #5316
 $f = 175$ Hz, KB window ($\alpha = 1.5$)



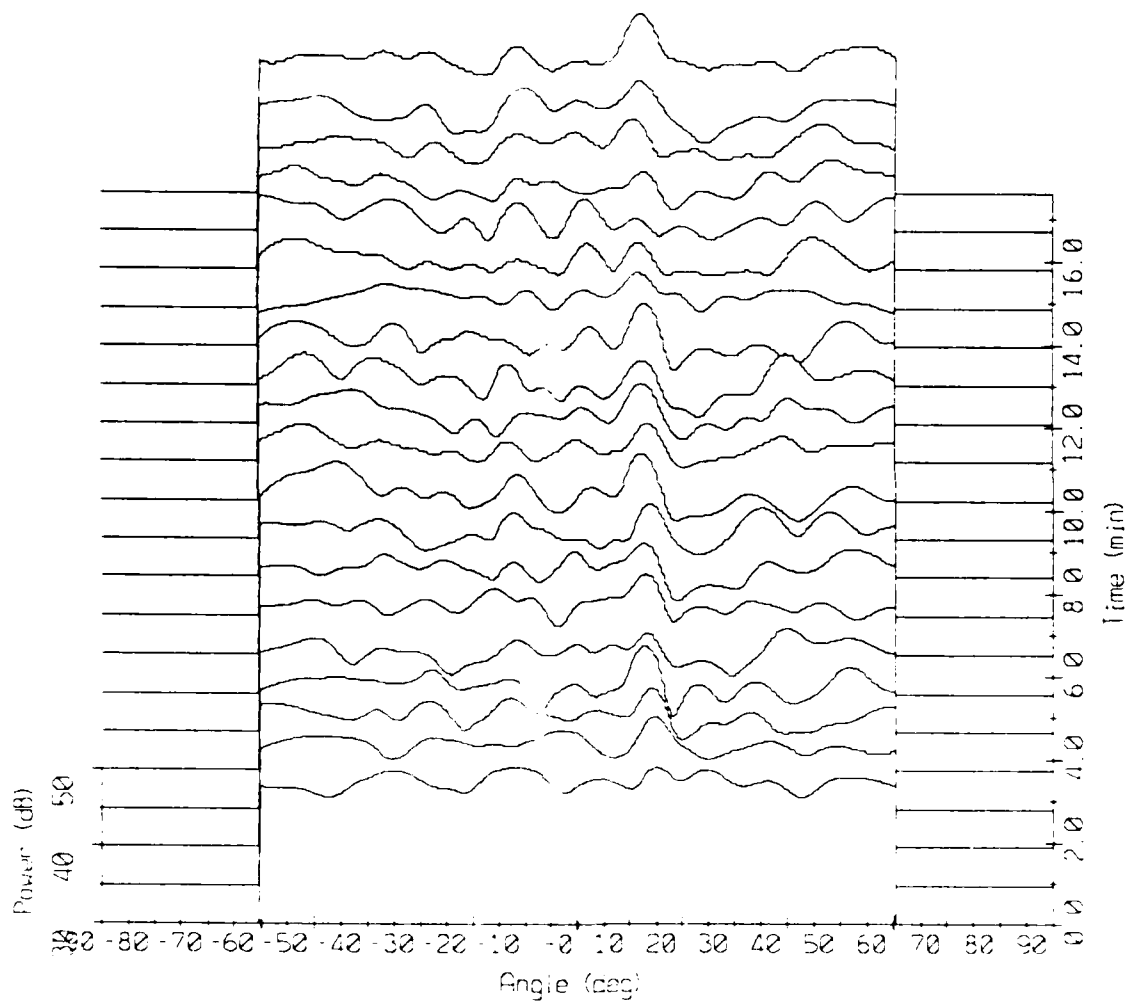
Array Response - 86060 Bin #5490
 $f = 200$ Hz, KB window ($\alpha = 1.5$)



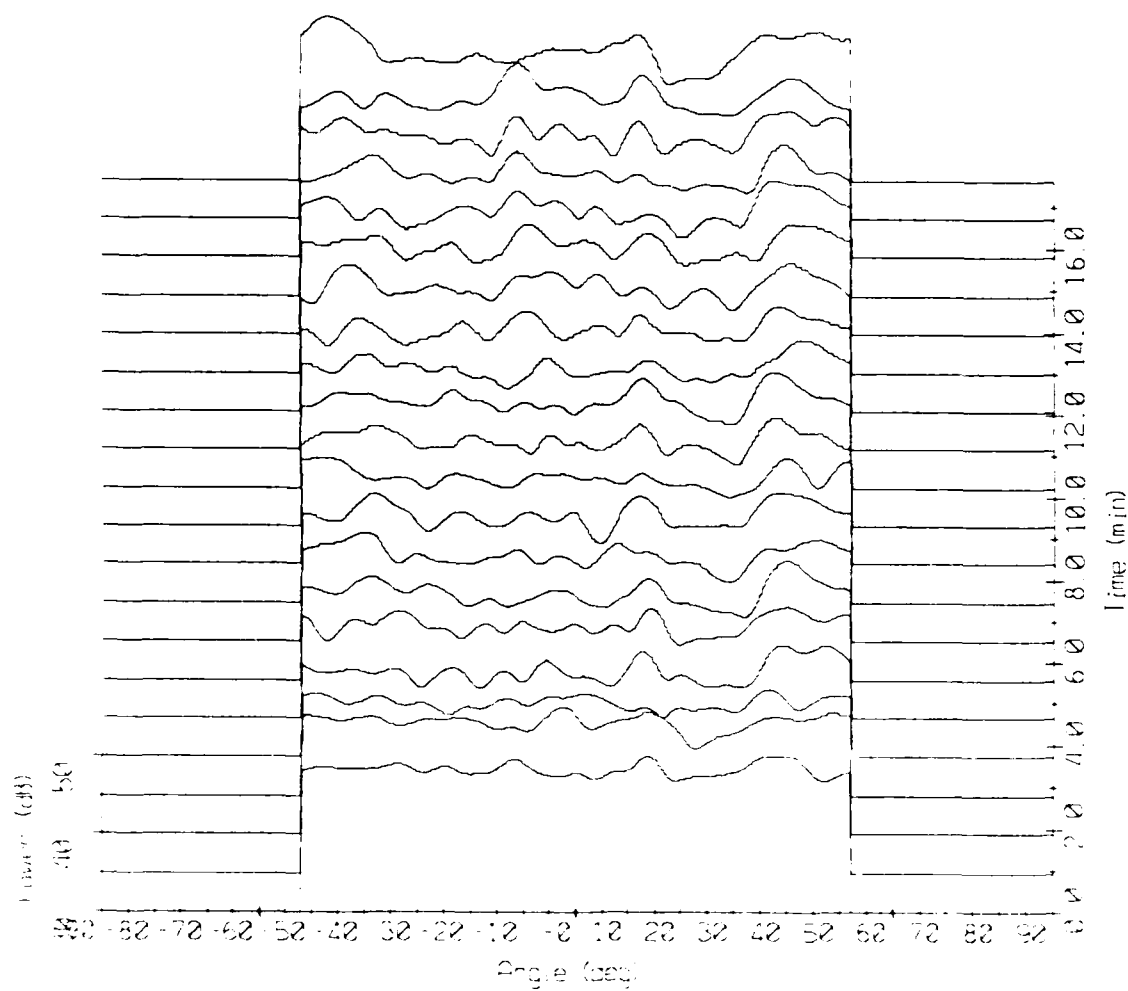
Array Response - 86060 Bin #5664
 $f = 225$ Hz, KB window ($\alpha = 1.5$)



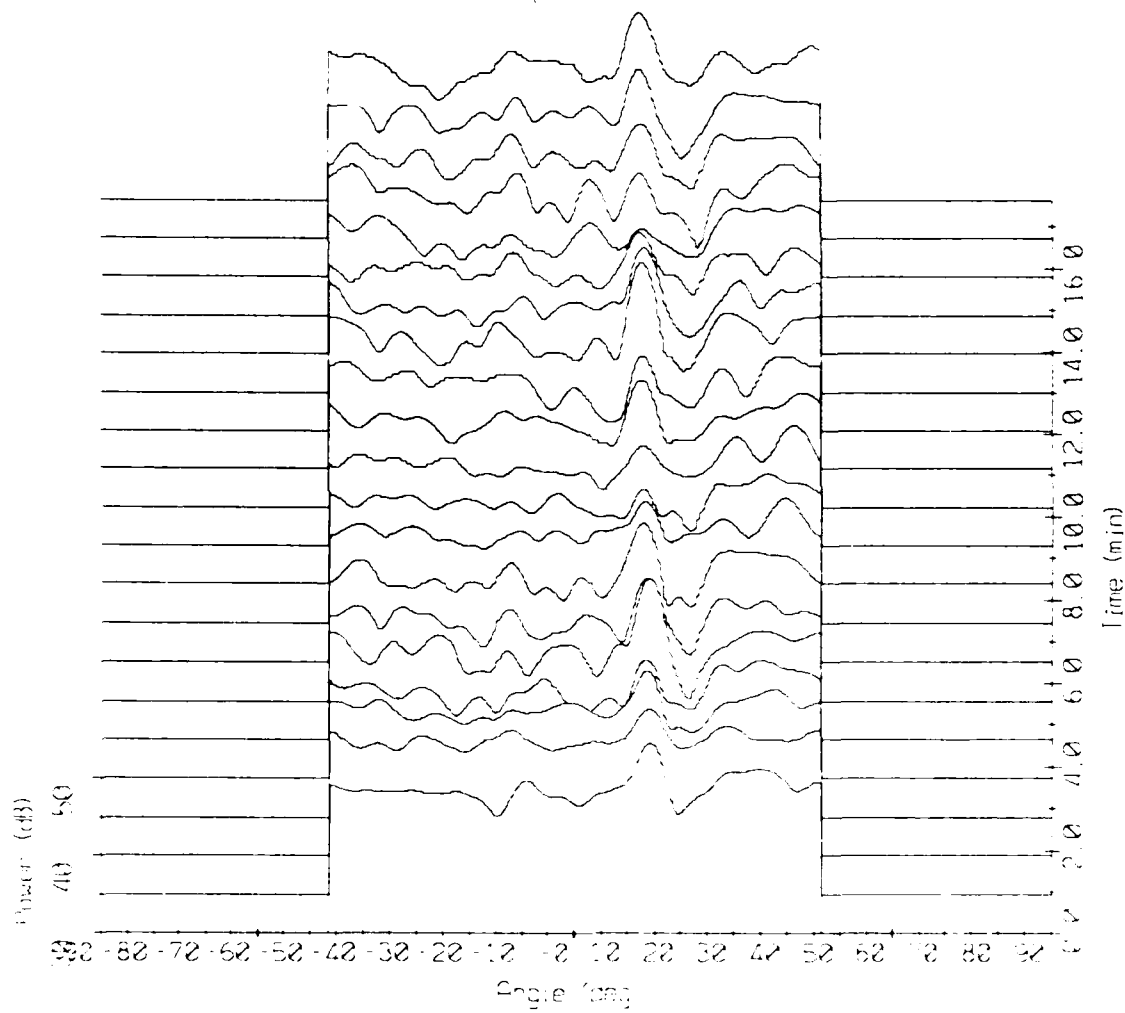
Array Response - 86060 Bin #5832
 $f = 250$ Hz, KB window ($\alpha = 1.5$)



Array Response - 86060 Bin #6012
 $f = 275$ Hz, KB window ($\alpha = 1.5$)

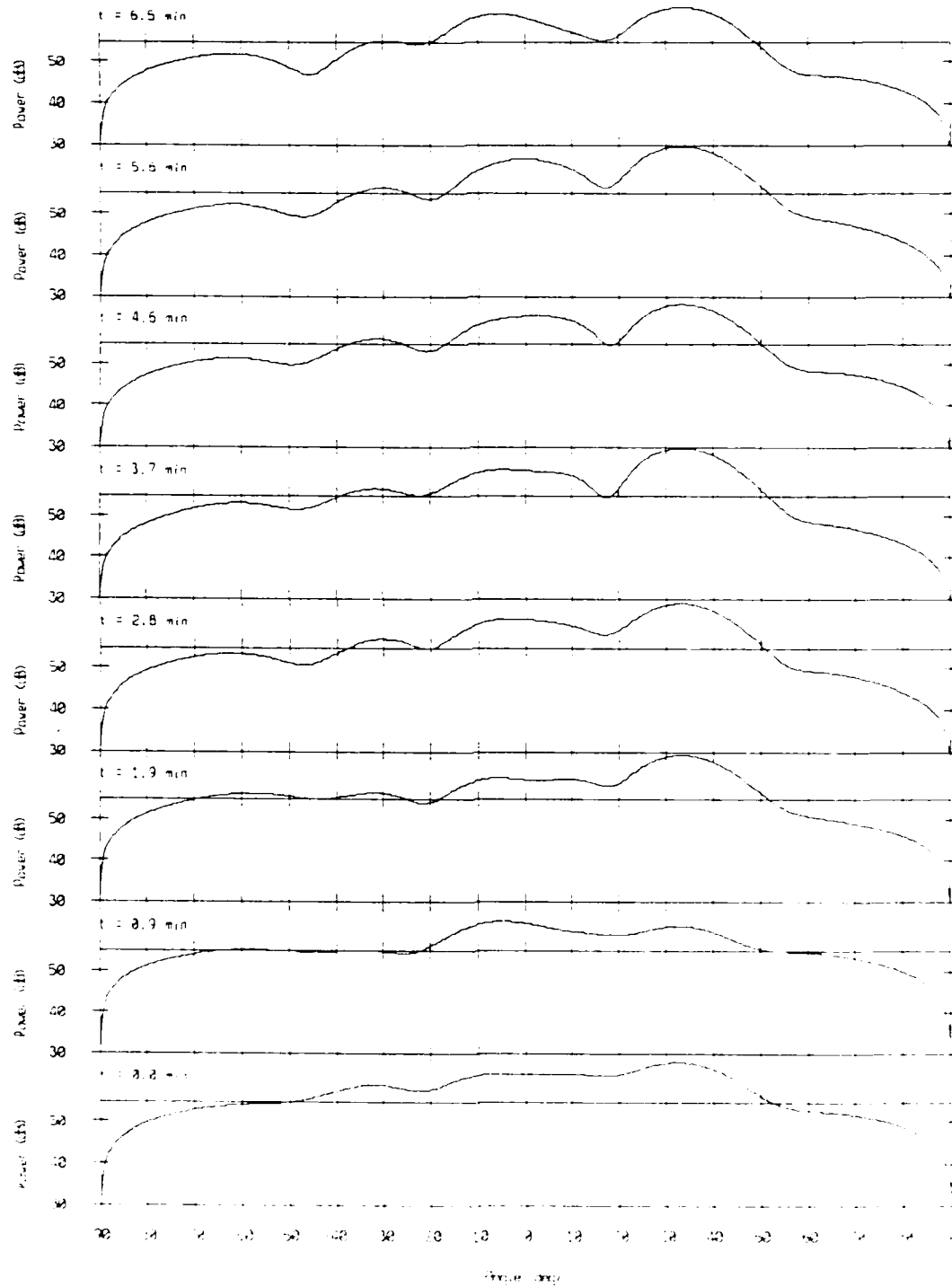


Array Response - 86060 Bin #6186
 $f = 300$ Hz, KB window ($\alpha = 1.5$)



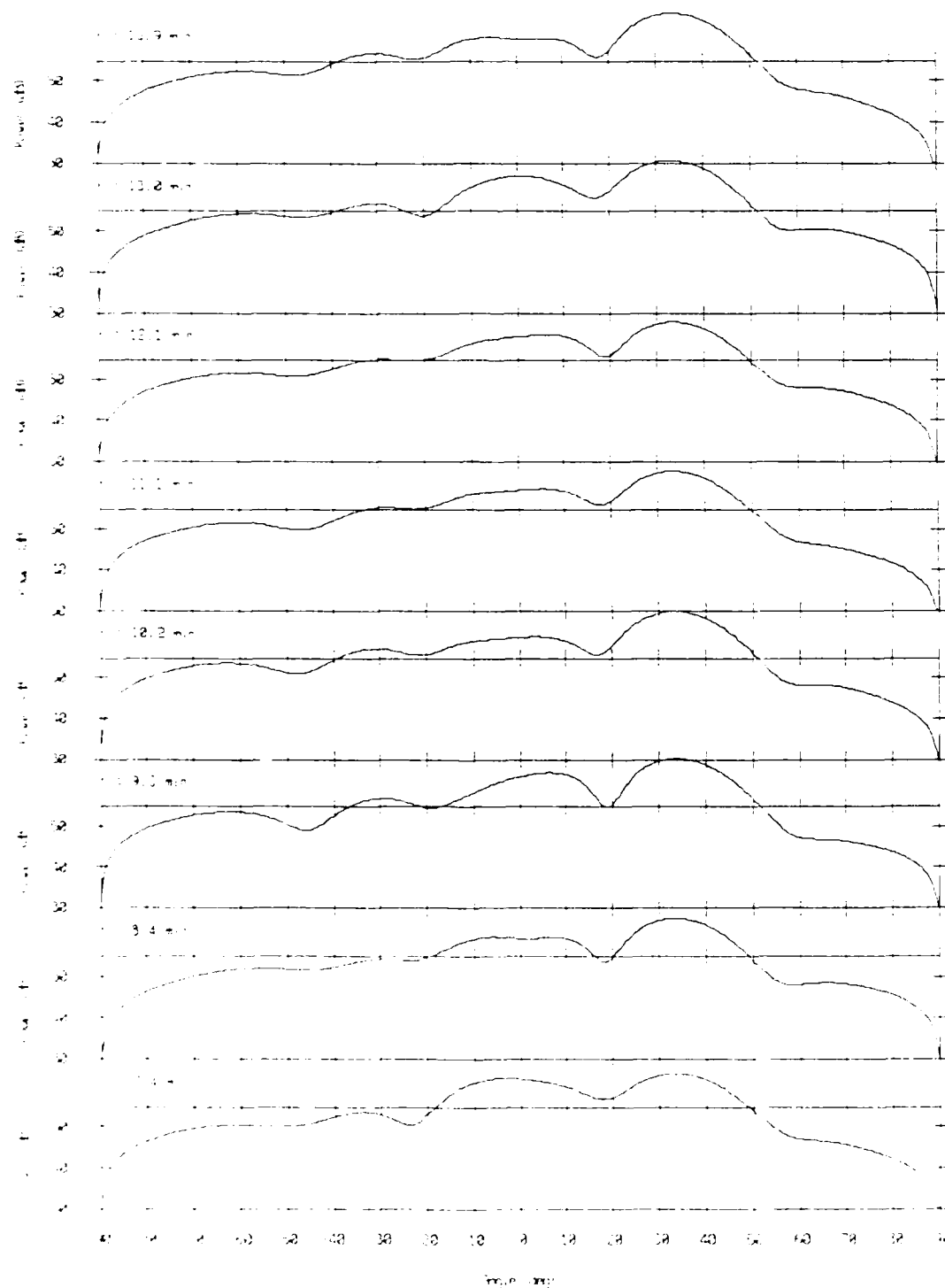
Array Response - 86060 Bin #4619

$f = 75$ Hz, KB window ($\alpha = 1.5$)



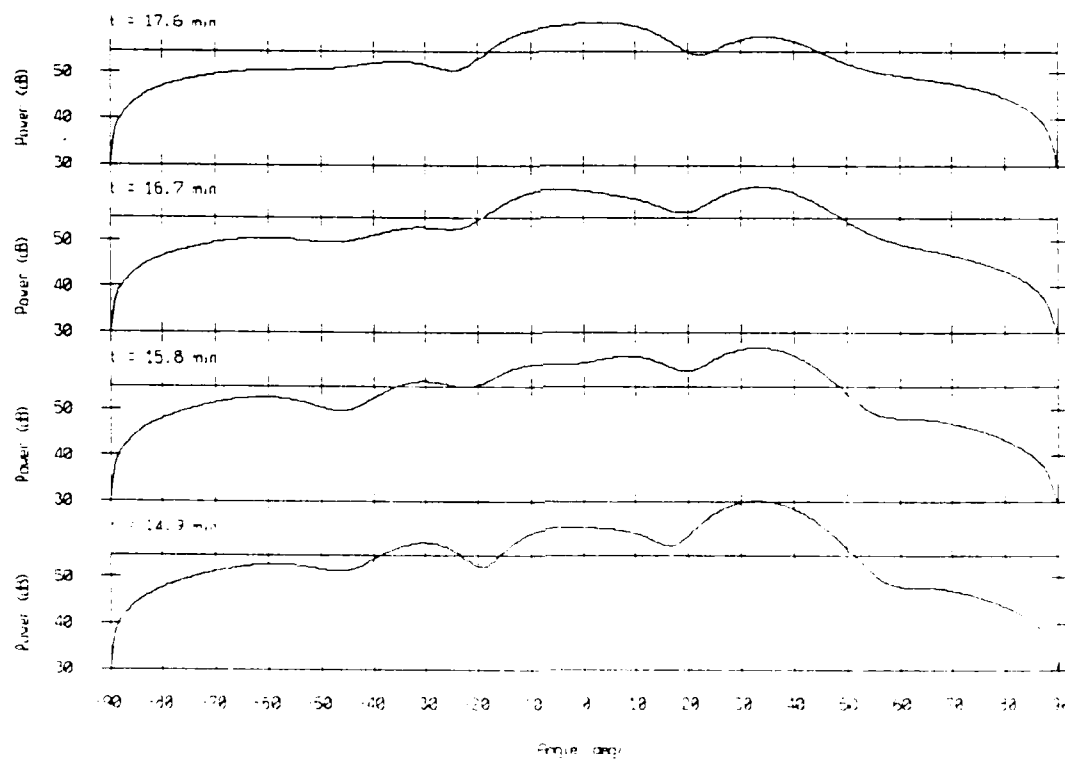
Binary Response - 86060 Bin #4619

$f = 75$ Hz, ΔB window (alpha = 1.5)



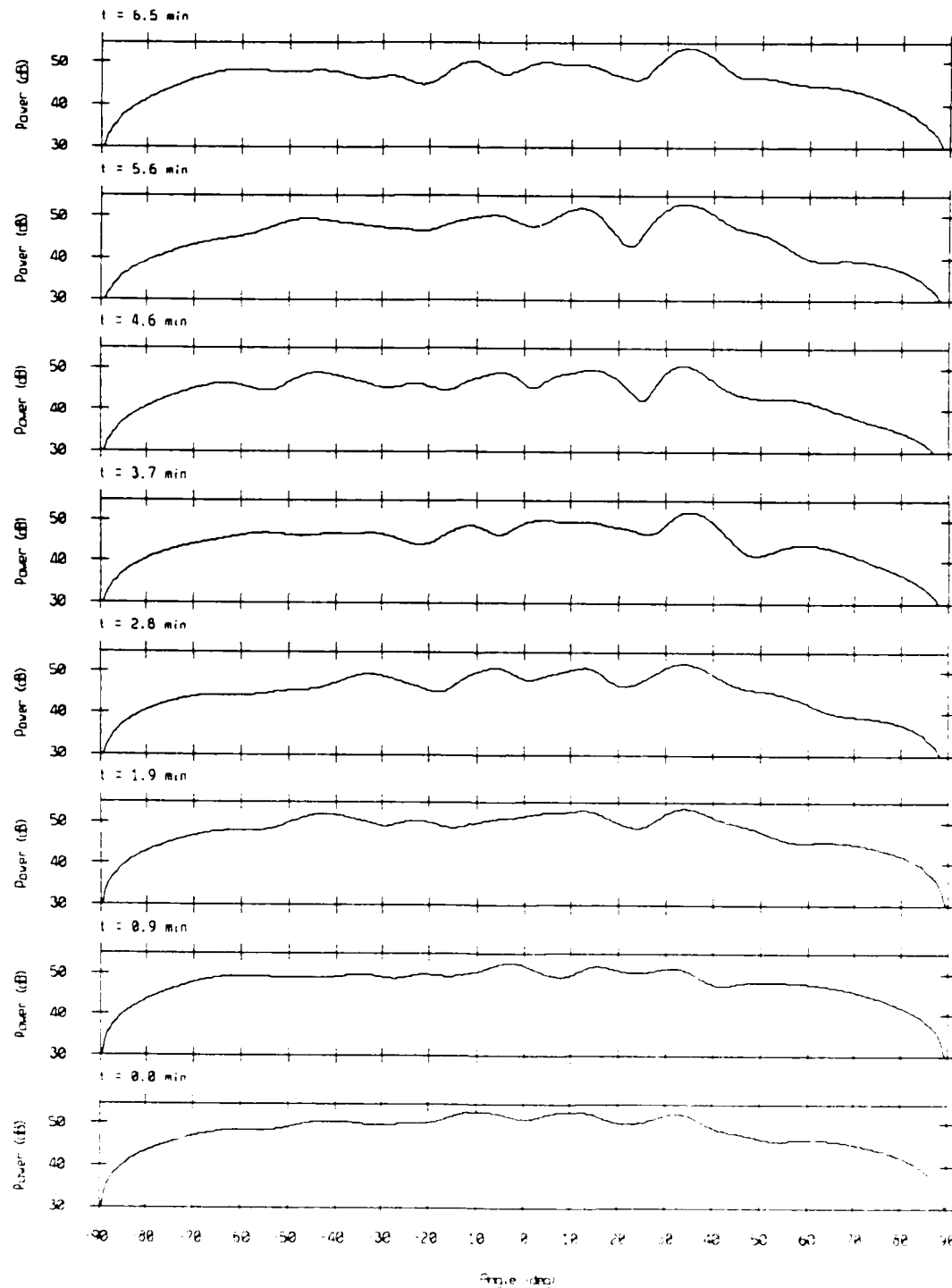
Array Response - 86060 Bin #4619

$f = 75$ Hz, KB window ($\alpha = 1.5$)



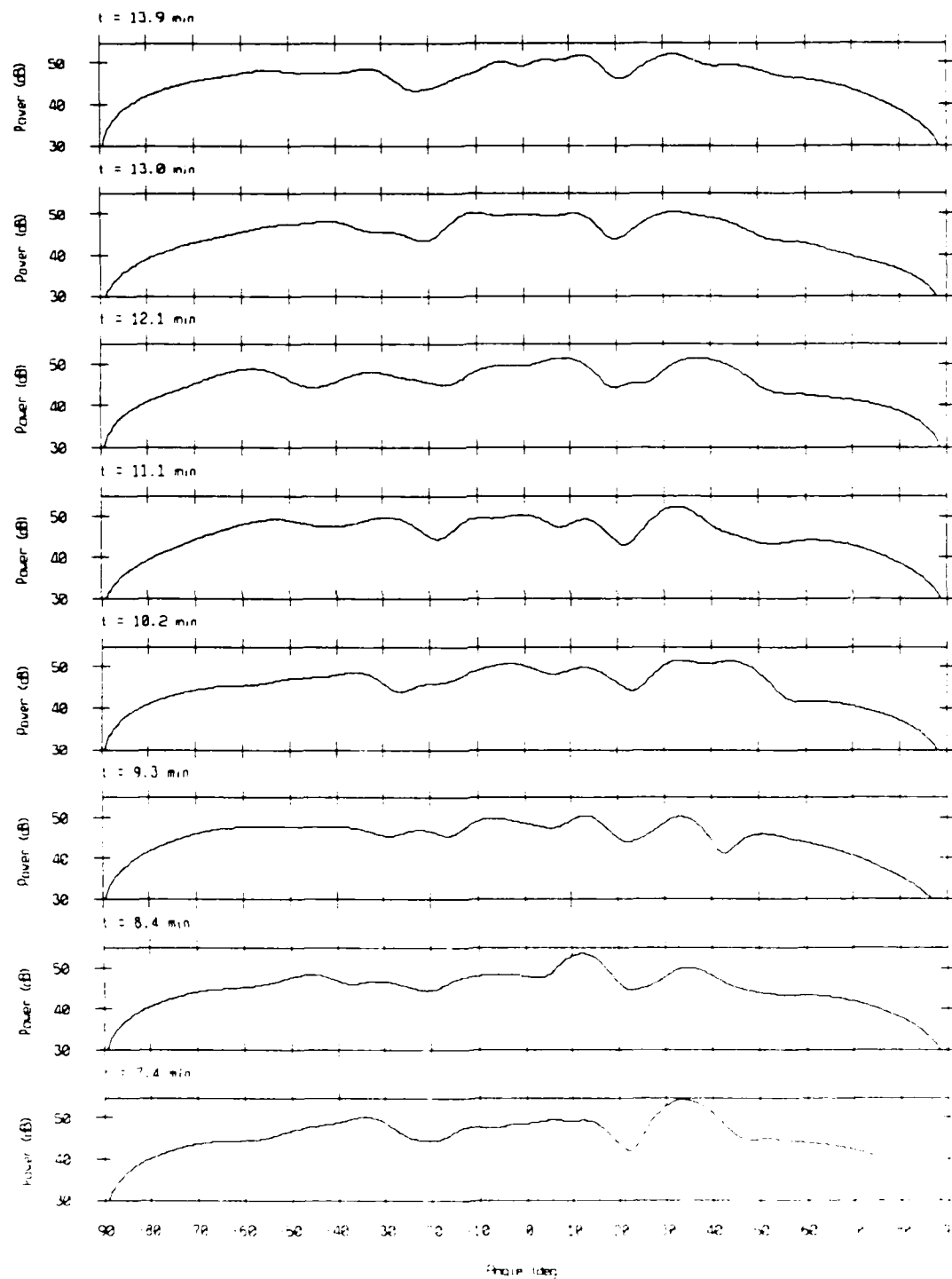
Array Response - 86060 Bin #5141

$f = 150$ Hz, KB window (alpha = 1.5)



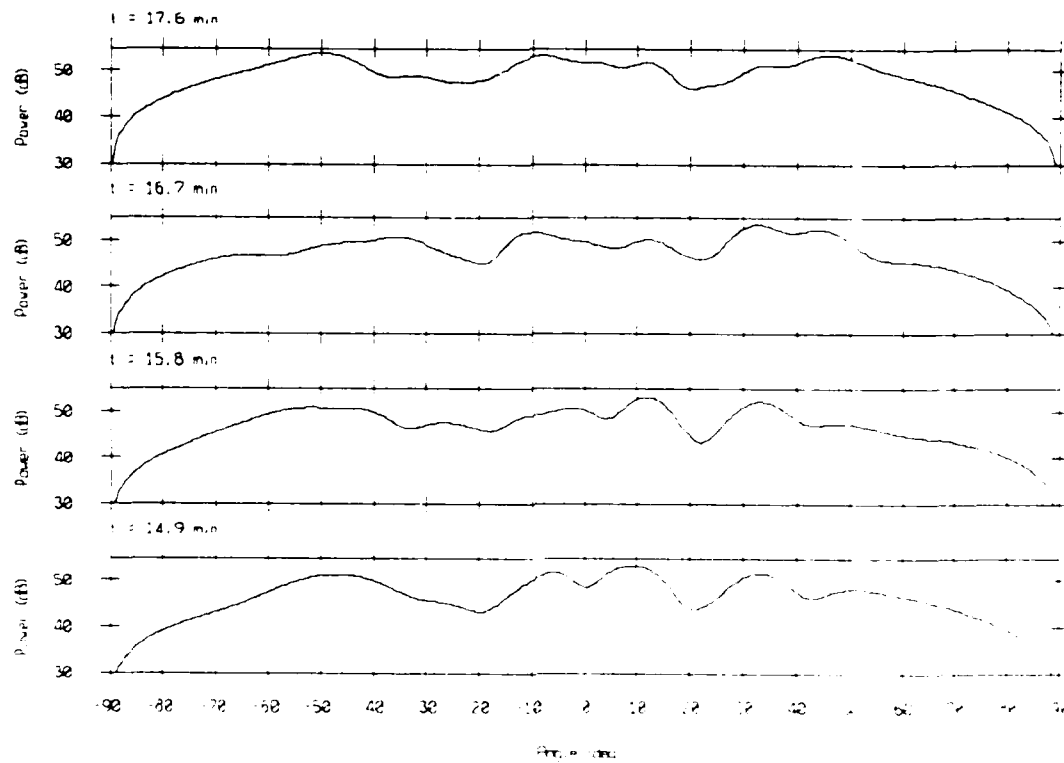
Array Response - 86060 Bin #5141

$f = 150$ Hz, KB window ($\alpha = 1.5$)



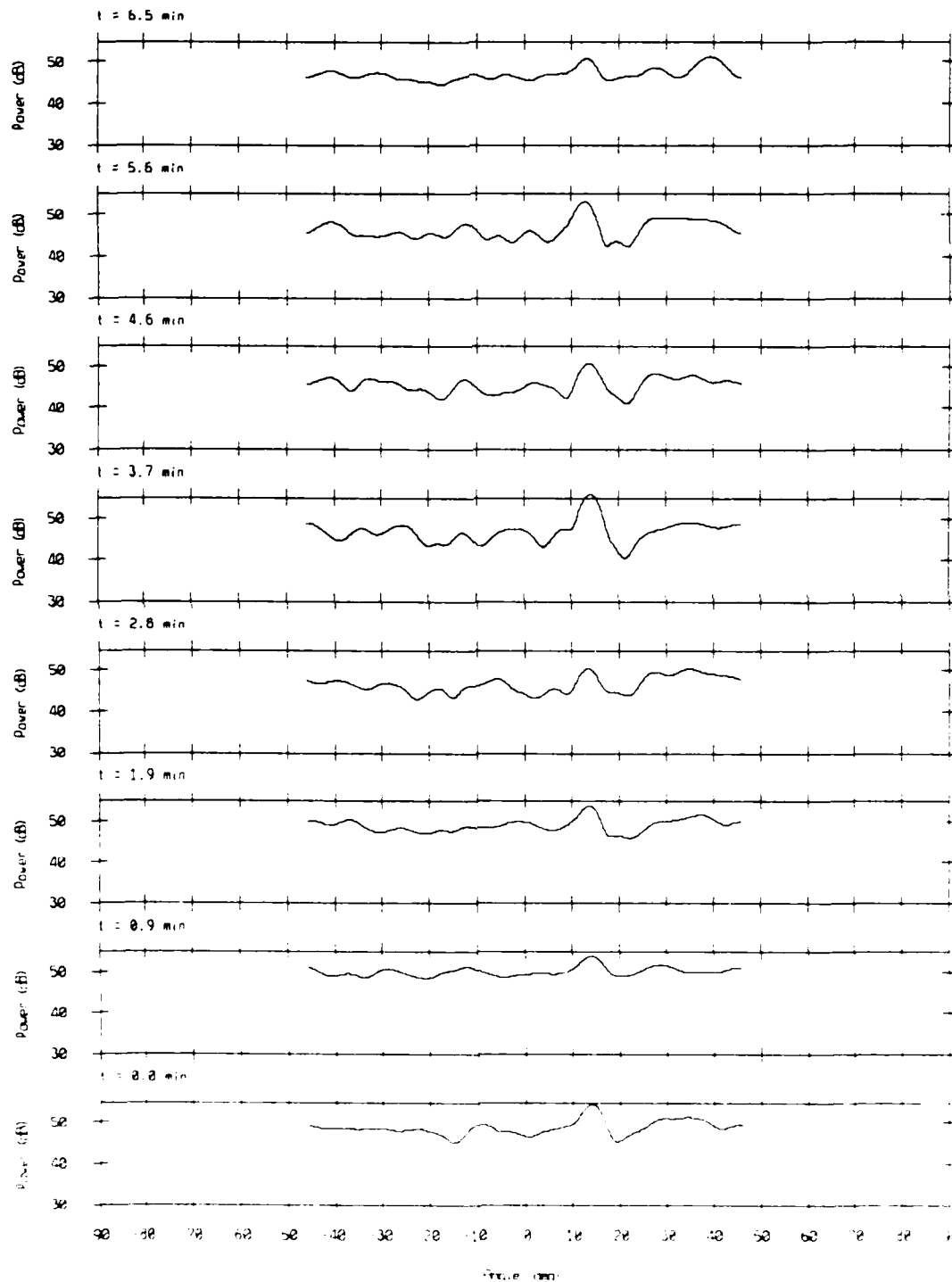
Array Response - 86060 Bin #5141

$f = 150$ Hz, KB window ($\alpha = 1.5$)



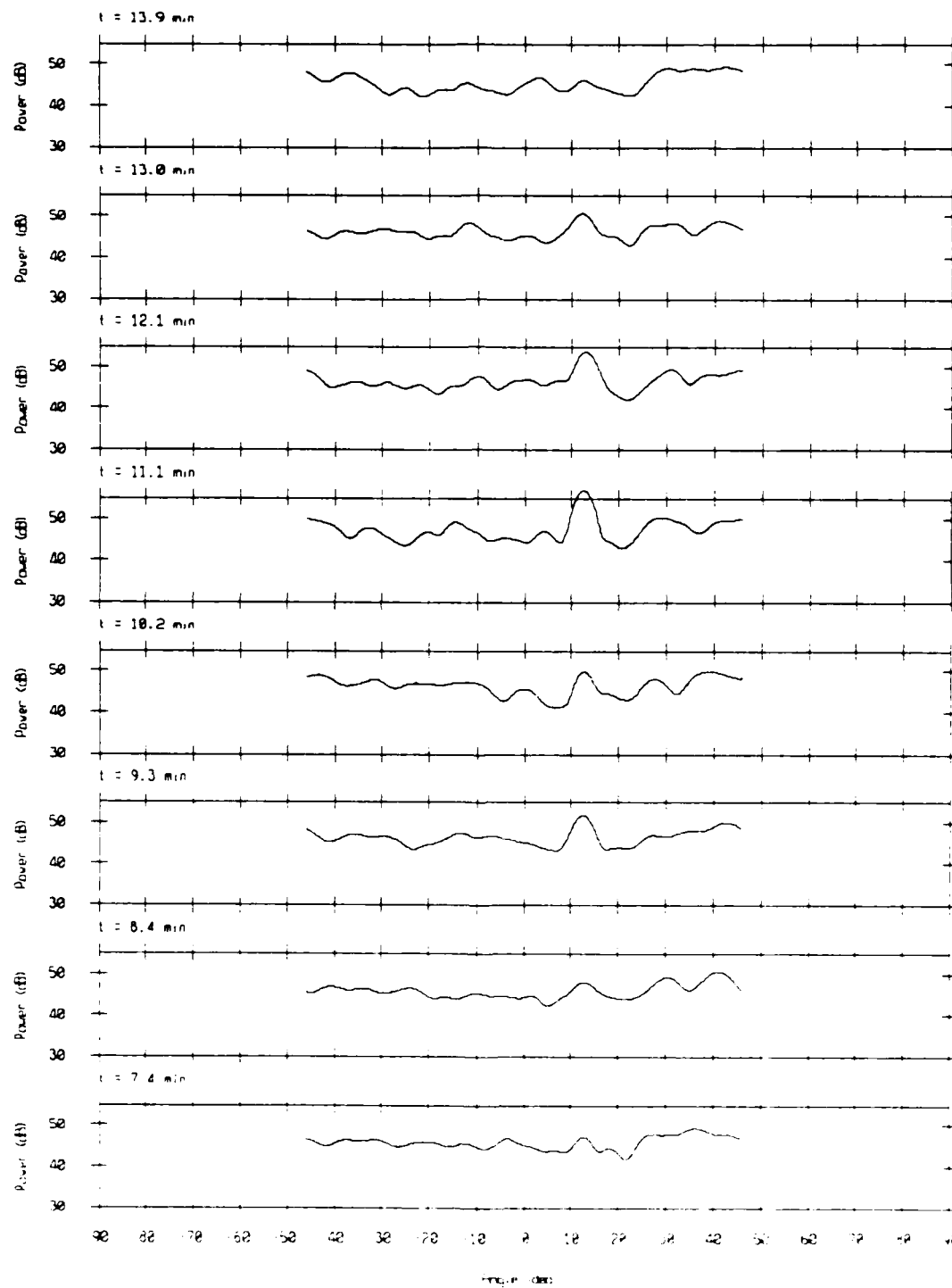
Array Response - 86060 Bin #6186

$f = 300$ Hz, KB window ($\alpha = 1.5$)



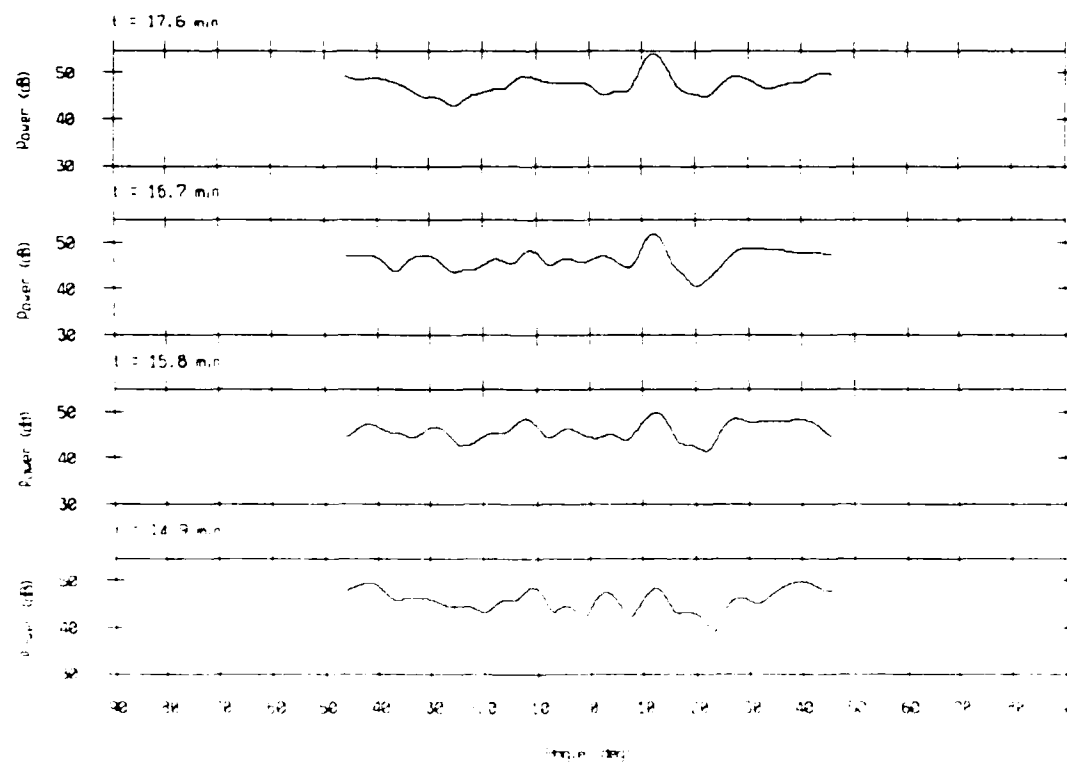
Array Response - 86060 Bin #6186

$f = 300$ Hz, KB window ($\alpha = 1.5$)



Array Response - 86060 Bin #6186

$f = 300$ Hz, KB window ($\alpha = 1.5$)



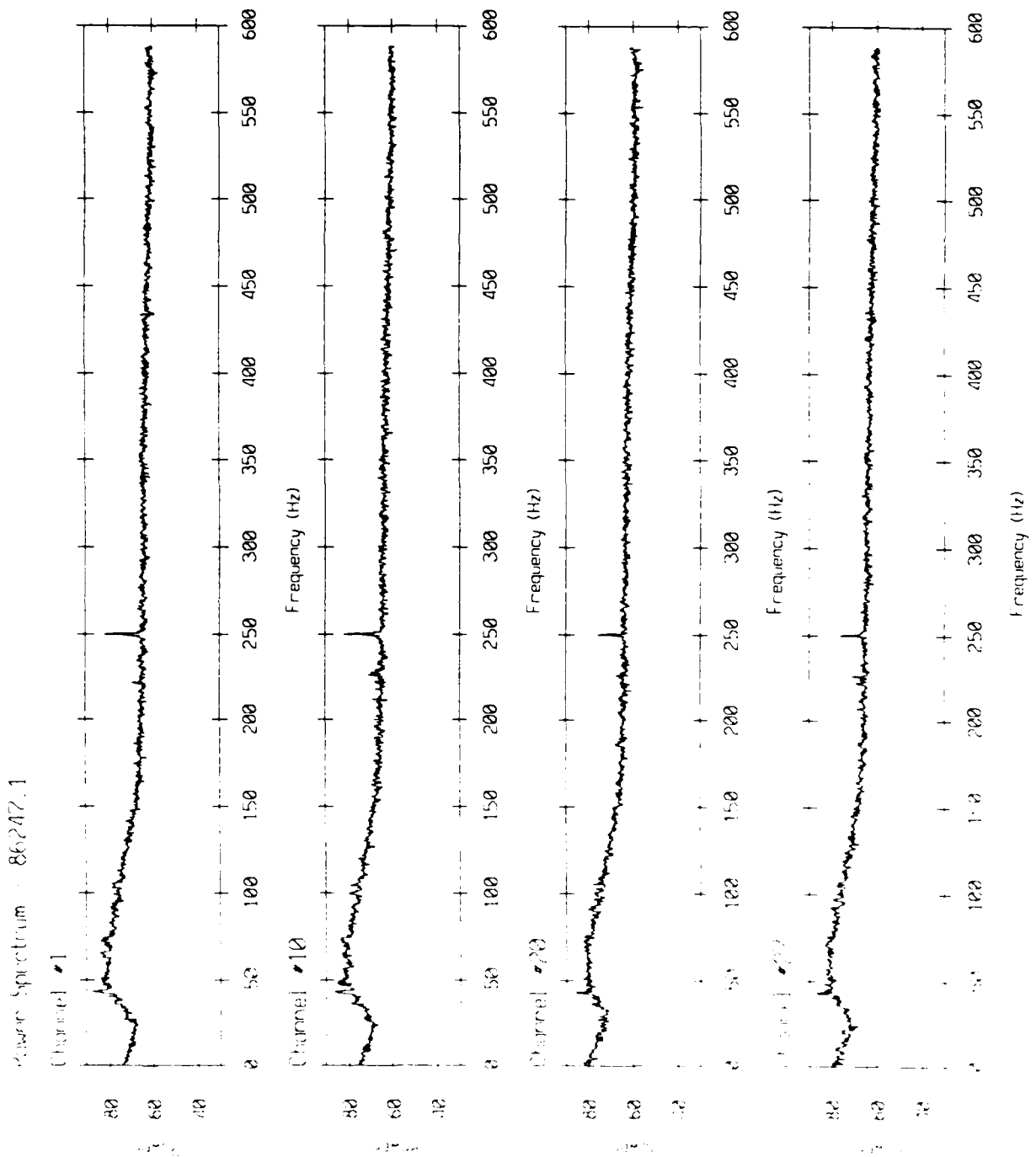


Figure 13.

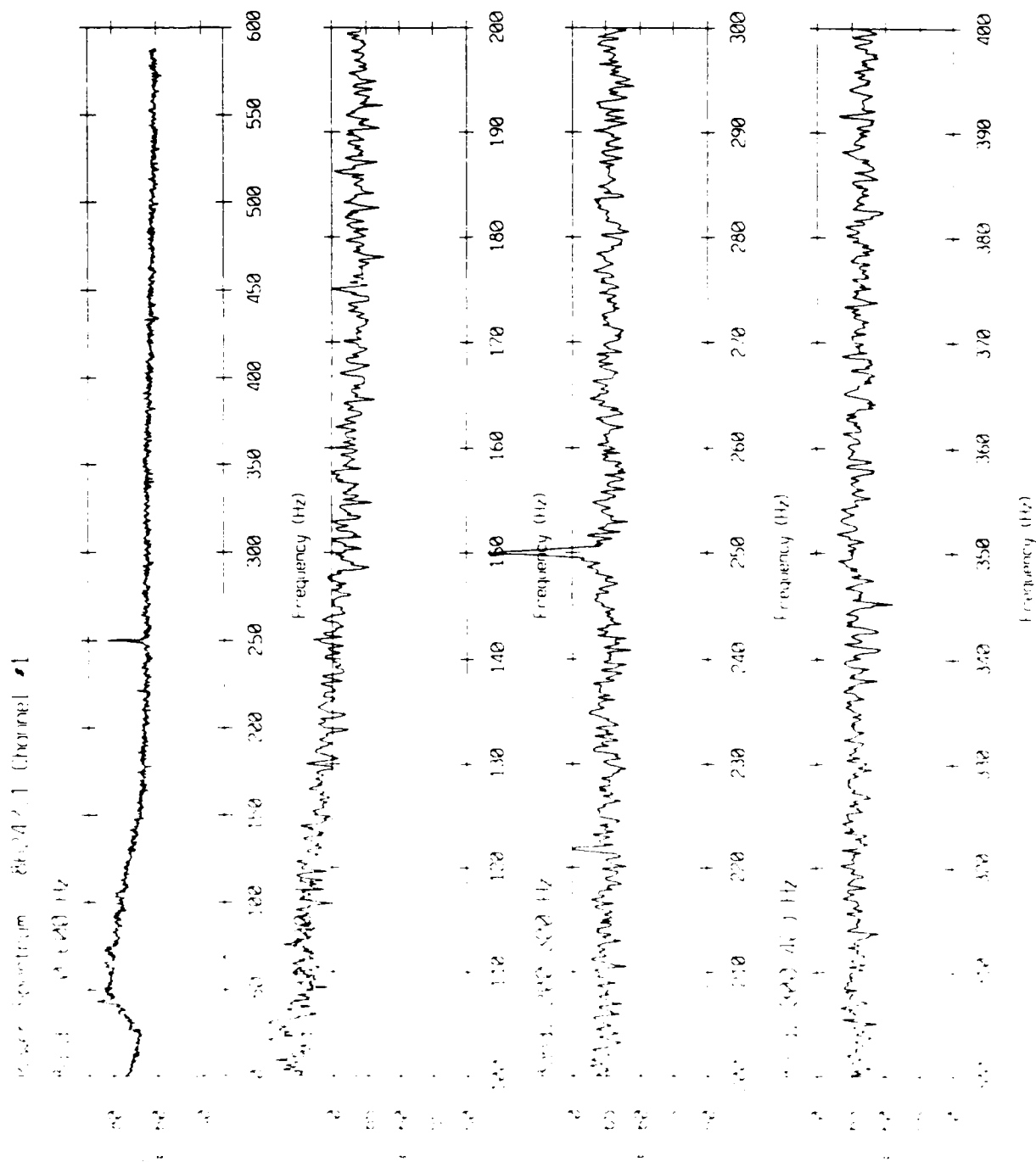


Figure 14(a).

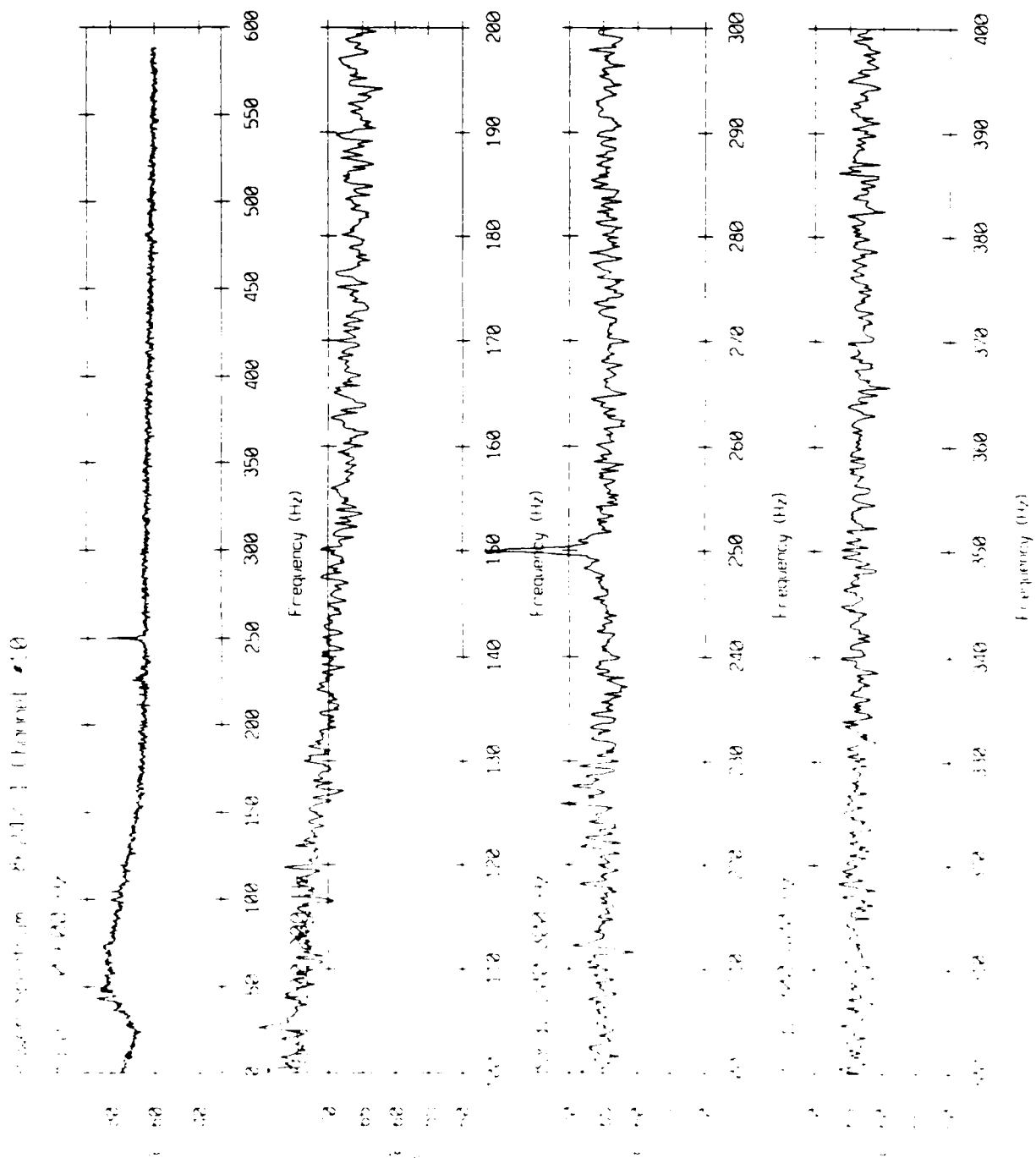
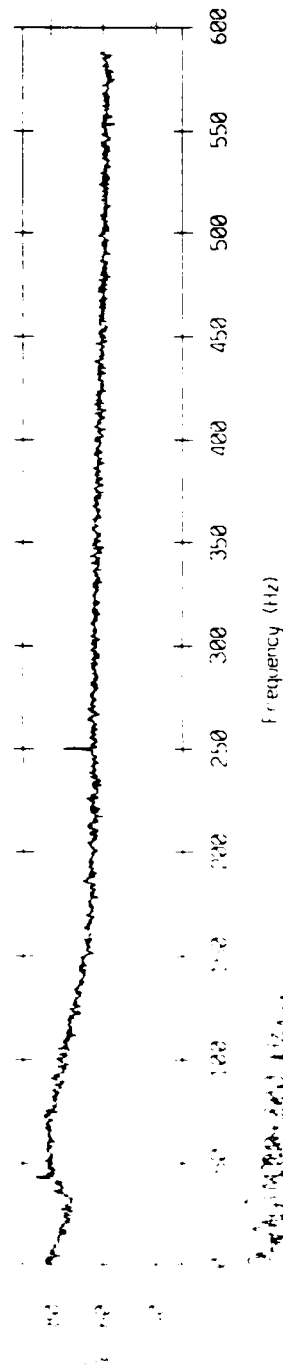


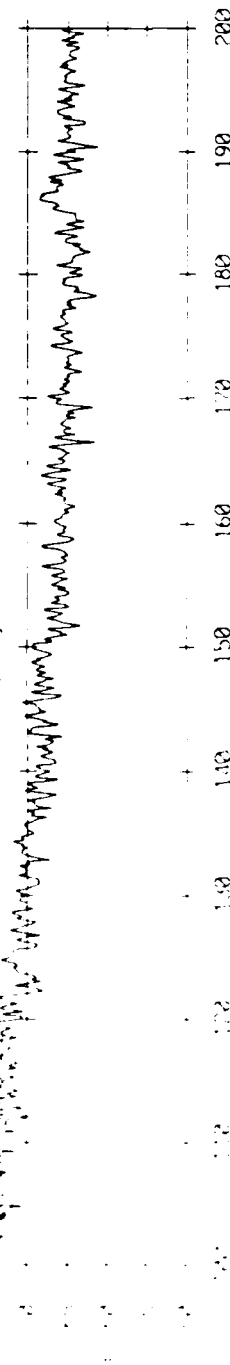
Figure 14(b).

Channel 20

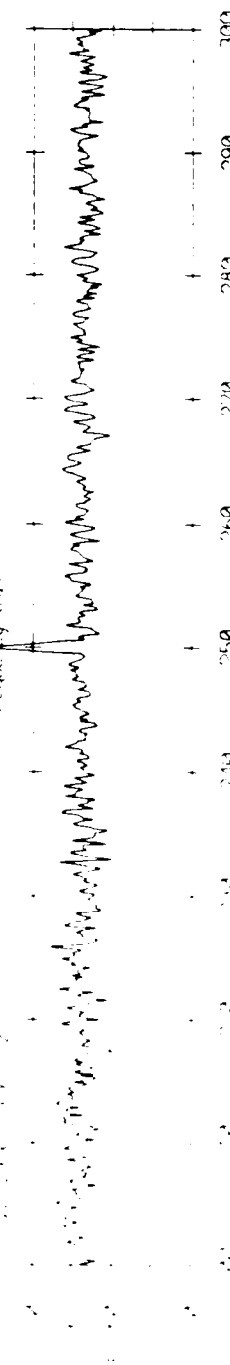
200 Hz



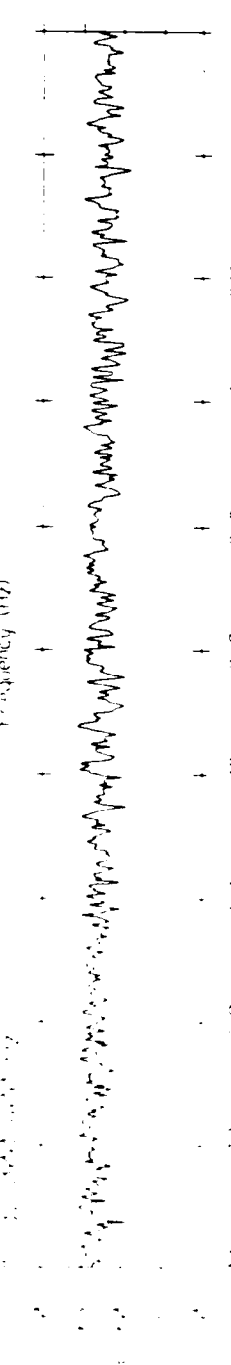
Frequency (Hz)



Frequency (Hz)



Frequency (Hz)

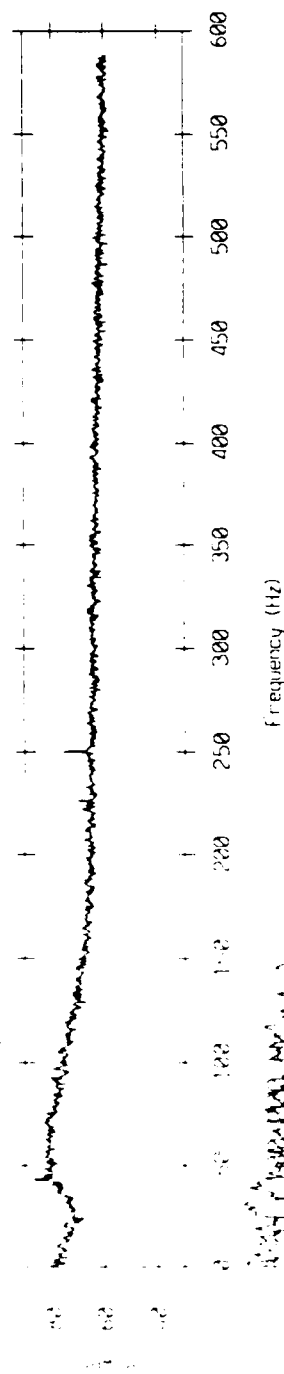


Frequency (Hz)

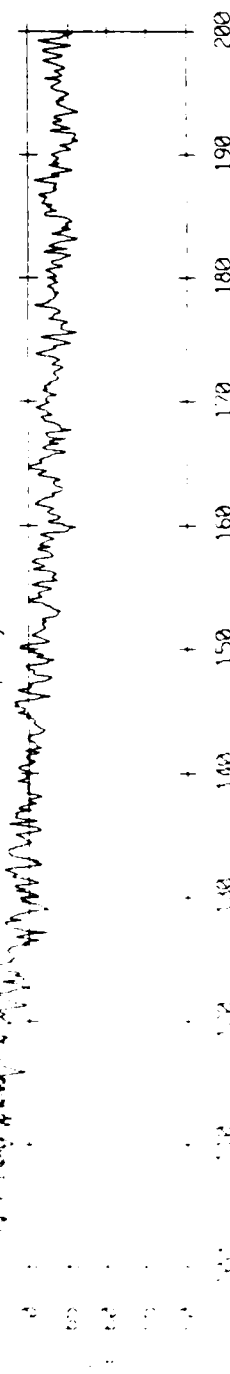
Figure 14(c).

Power Spectrum - 80.1 Hz - Channel 222

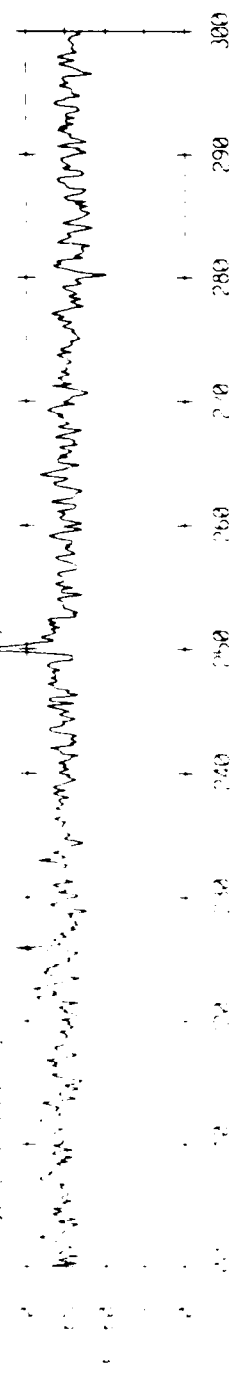
Power - 0.1 dB/Hz



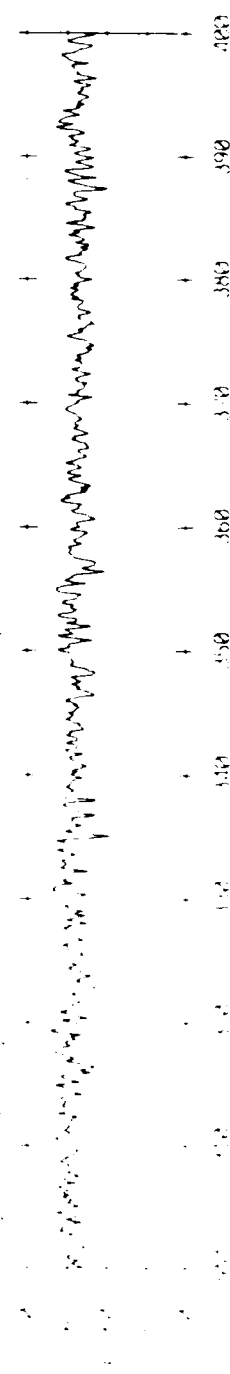
Frequency (Hz)



Frequency (Hz)



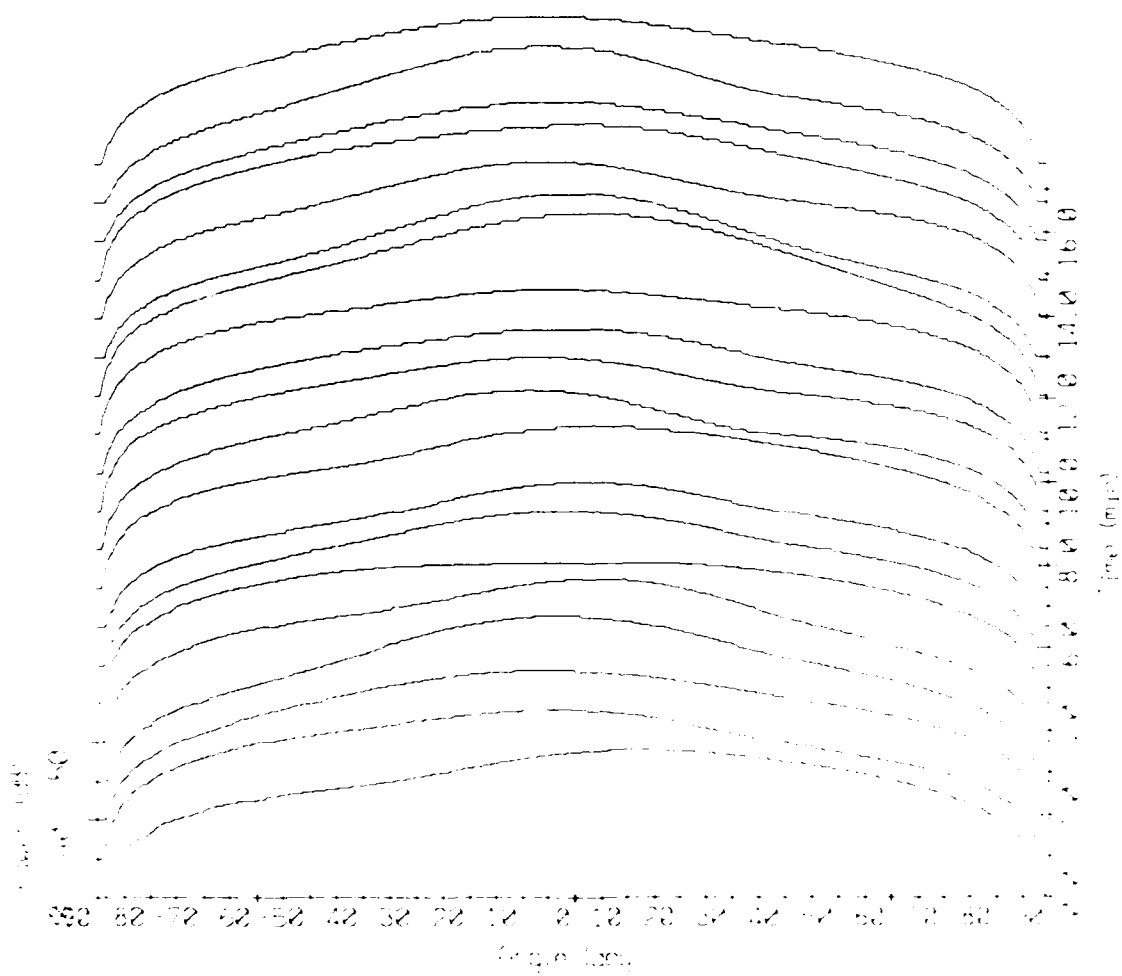
Frequency (Hz)

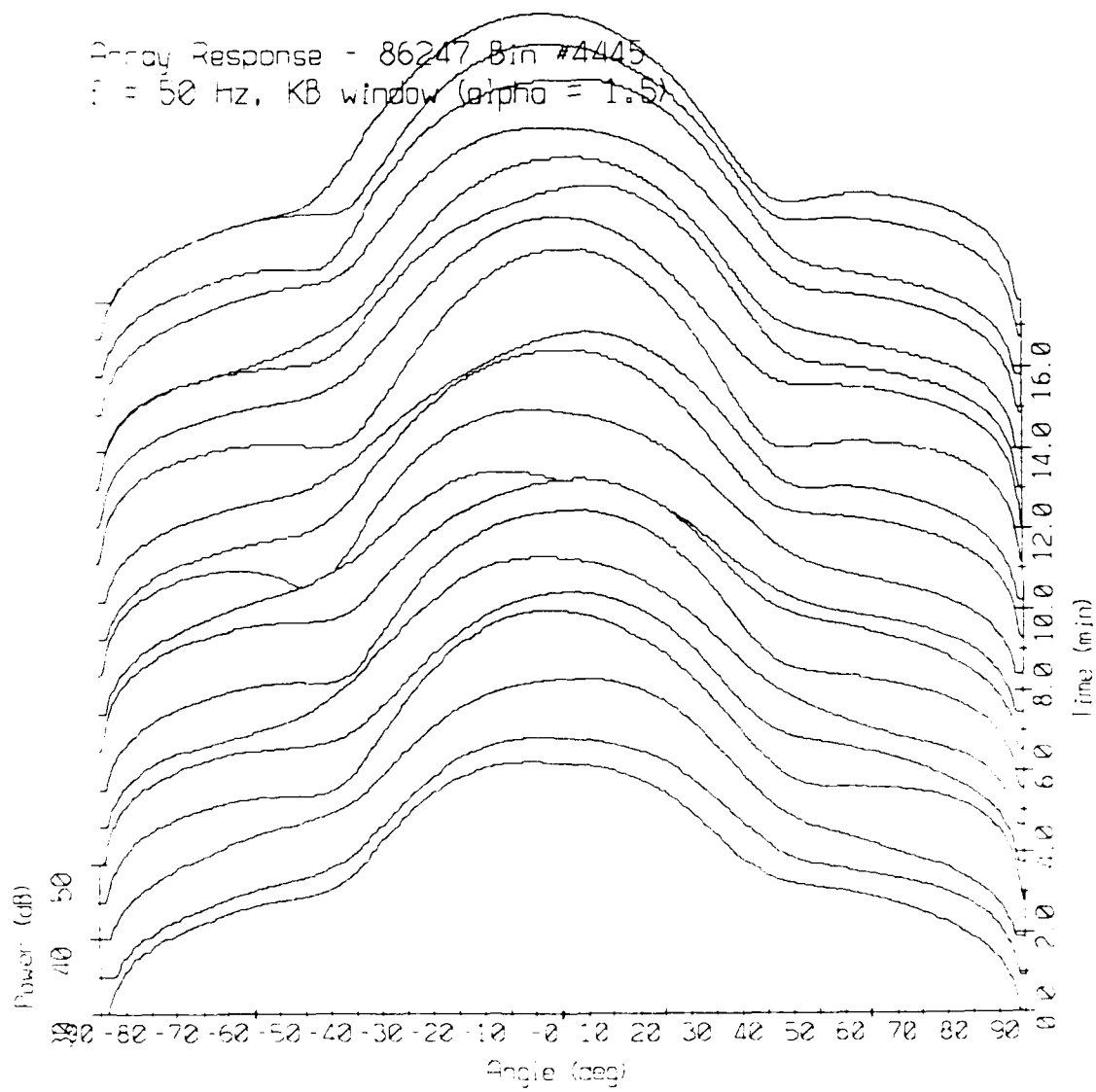


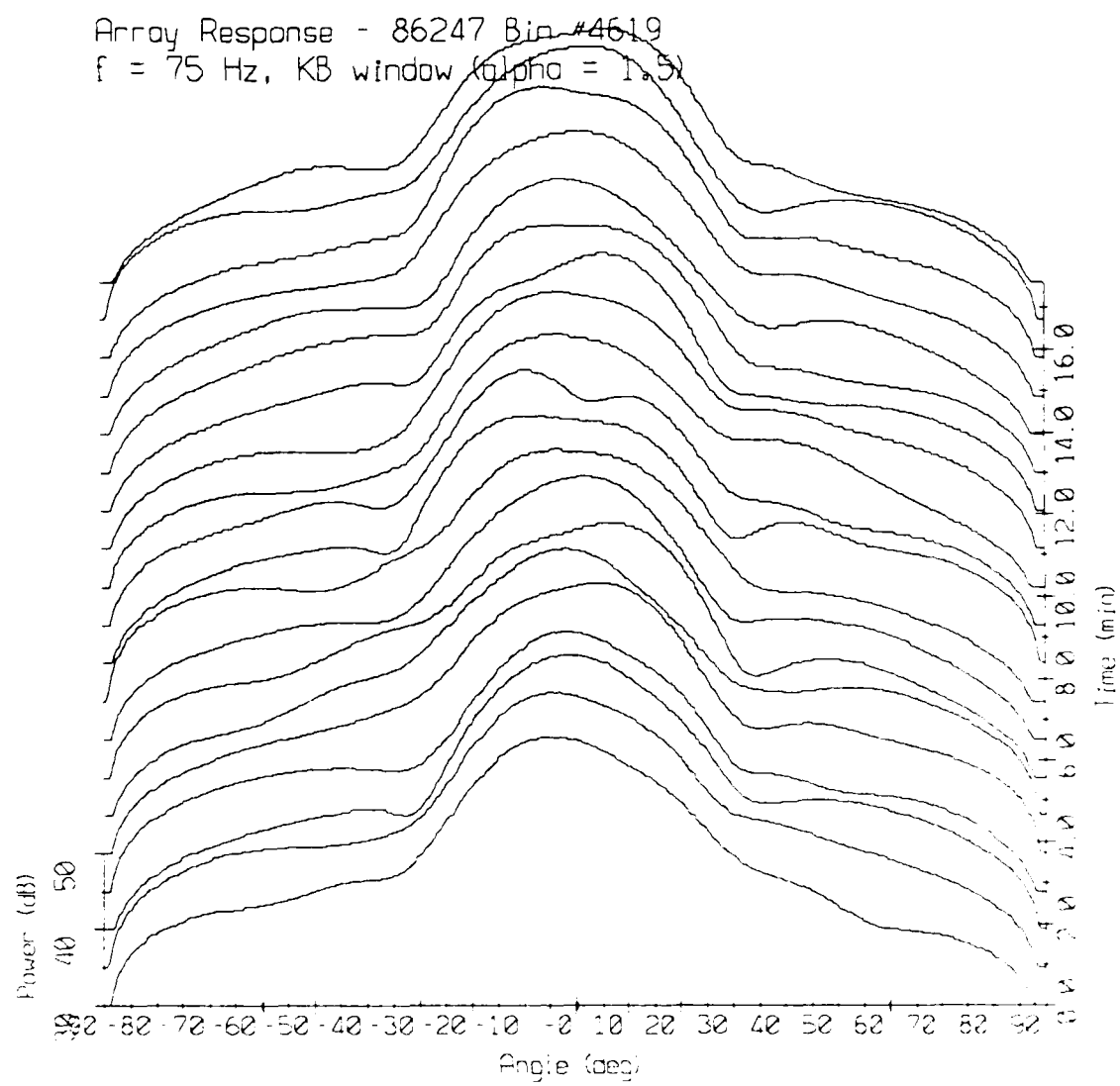
Frequency (Hz)

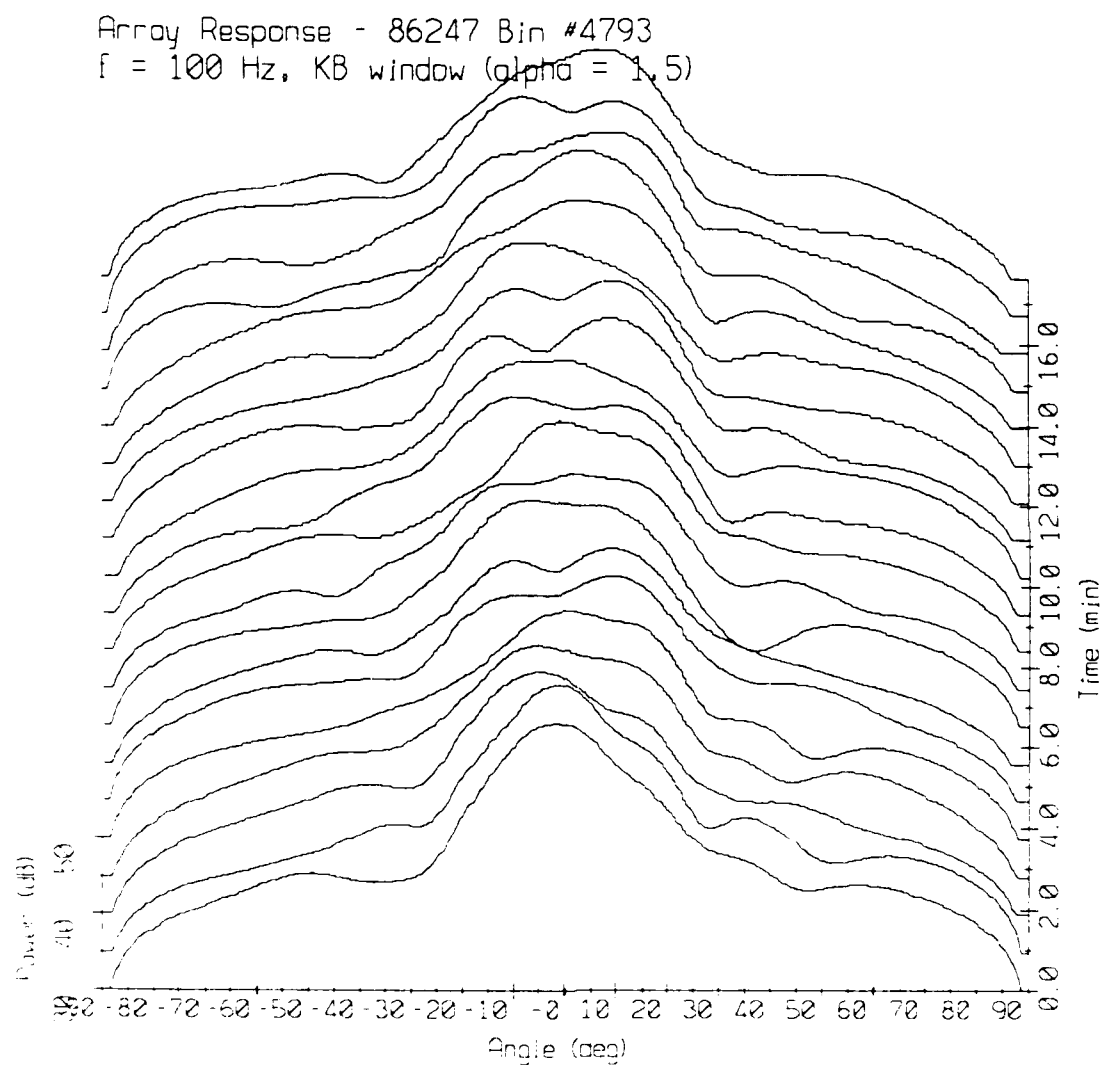
Figure 14.17.

Array Response - 86247 Bin #4271
 $f = 25$ Hz, KB window ($\alpha = 1.5$)

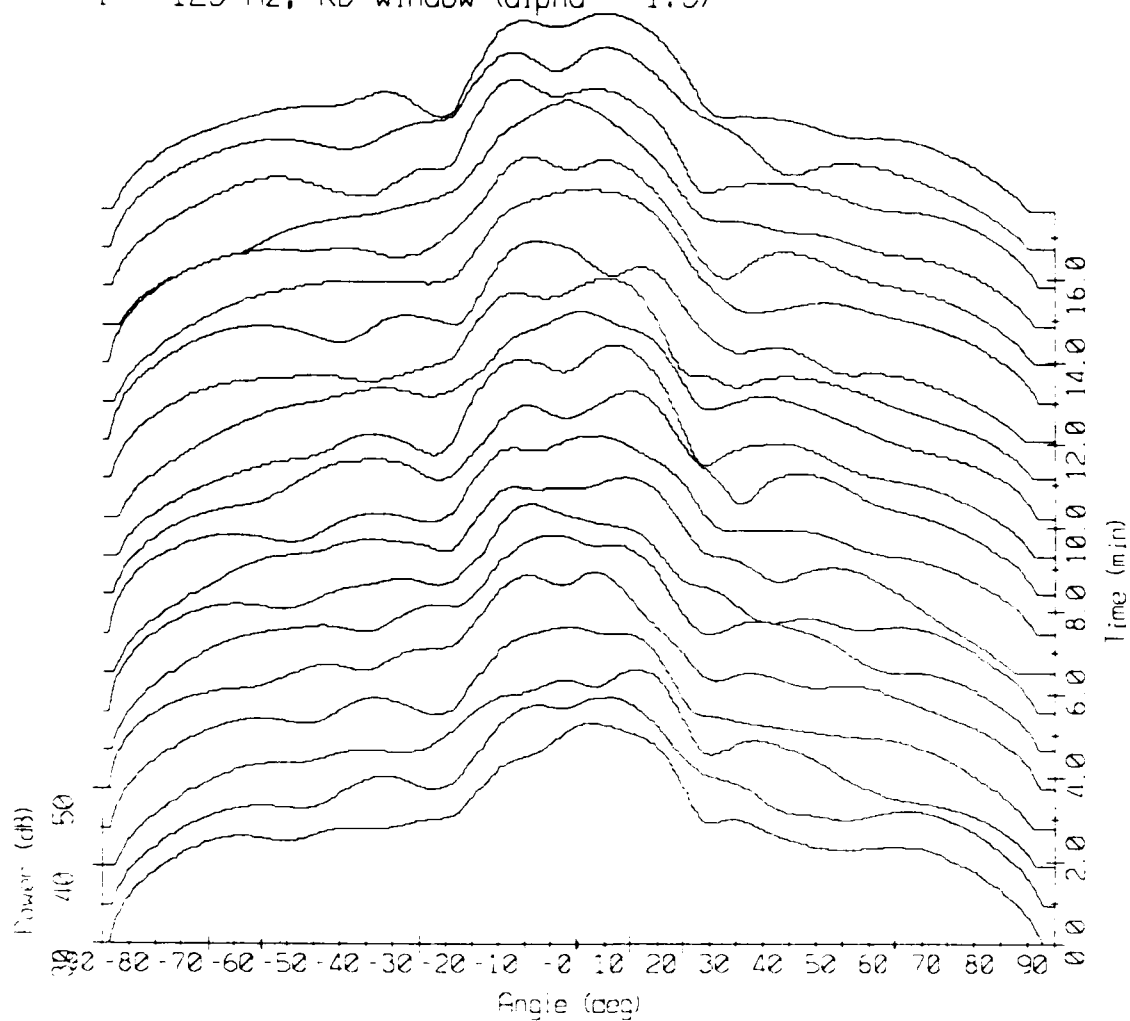




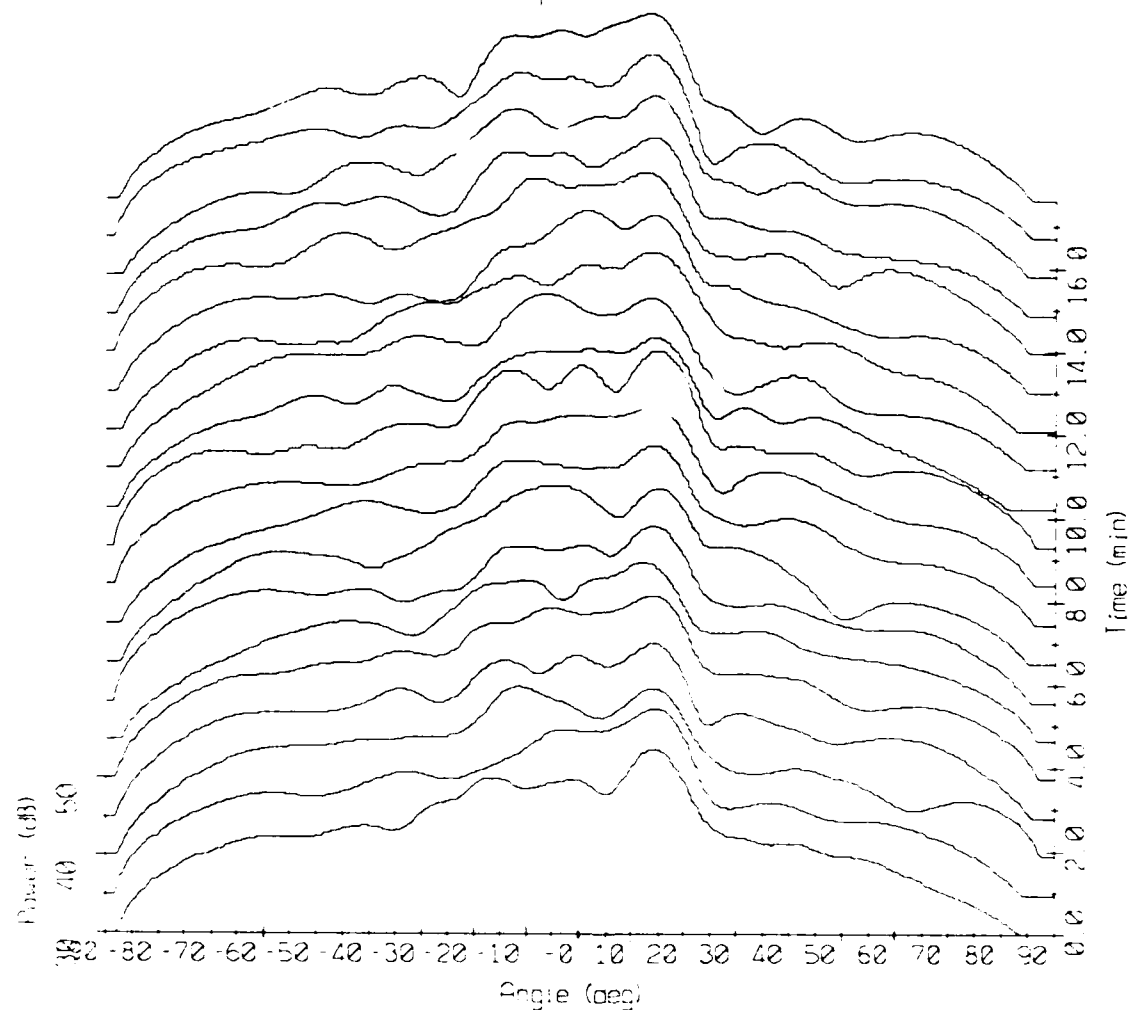




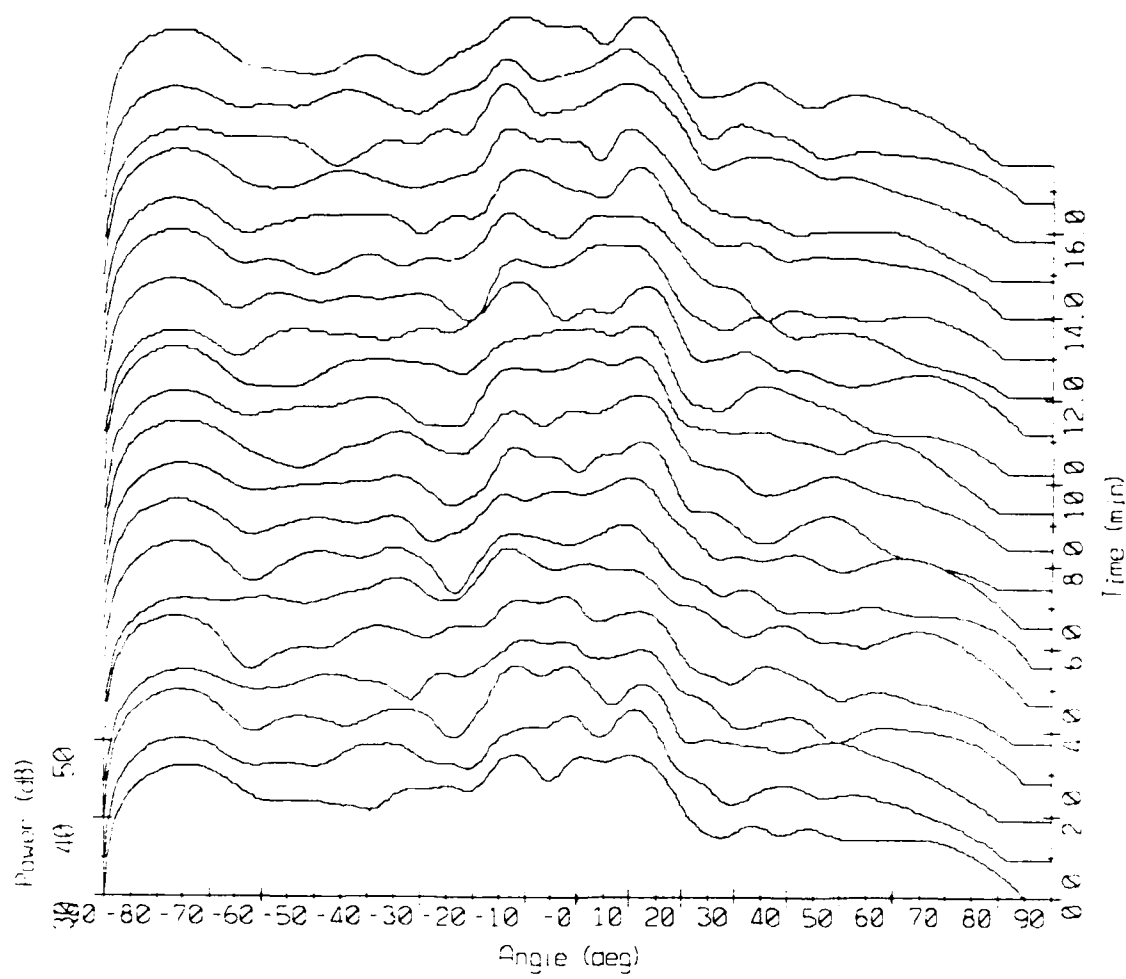
Array Response - 86247 Bin #4967
 $f = 125$ Hz, KB window ($\alpha = 1.5$)



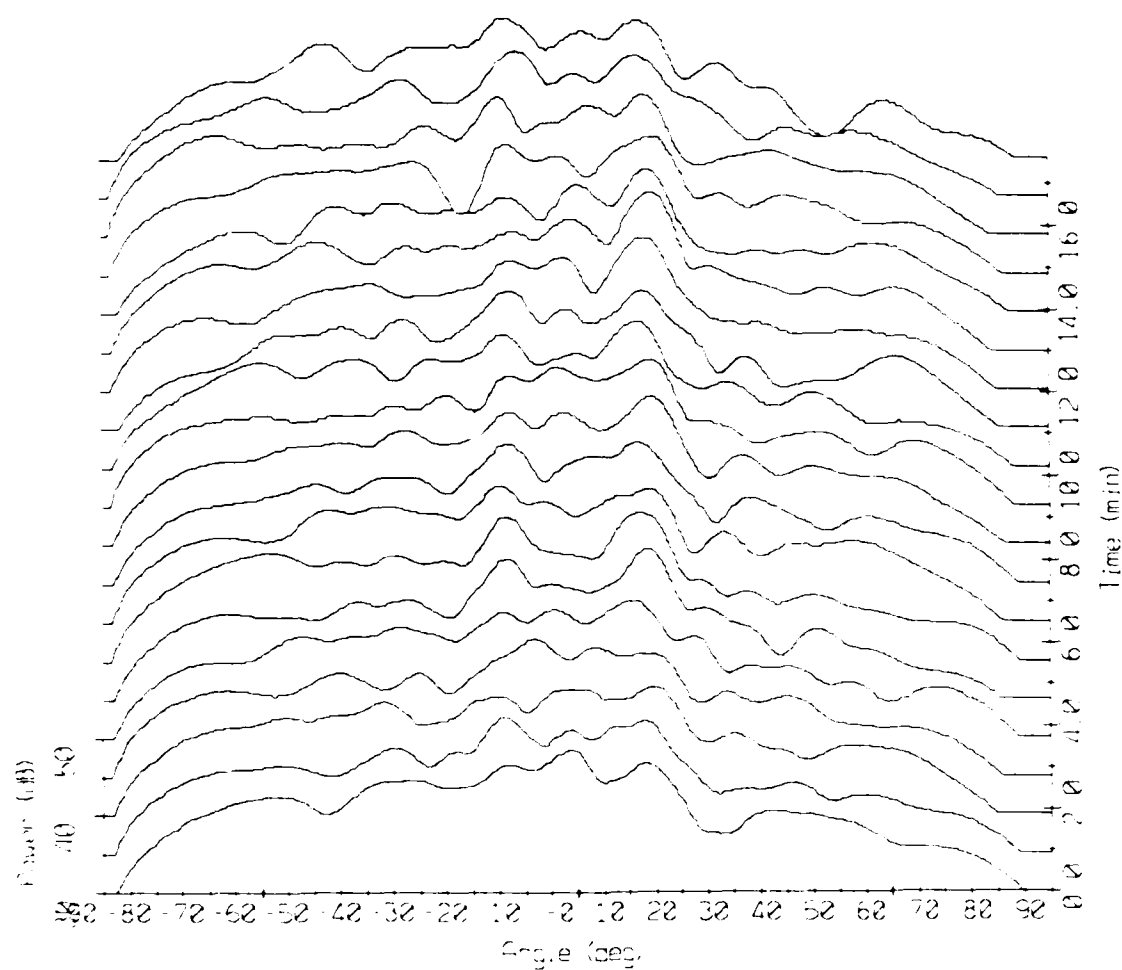
Array Response - 86247 Bin #5141
 $f = 150$ Hz, KB window ($\alpha = 1.5$)



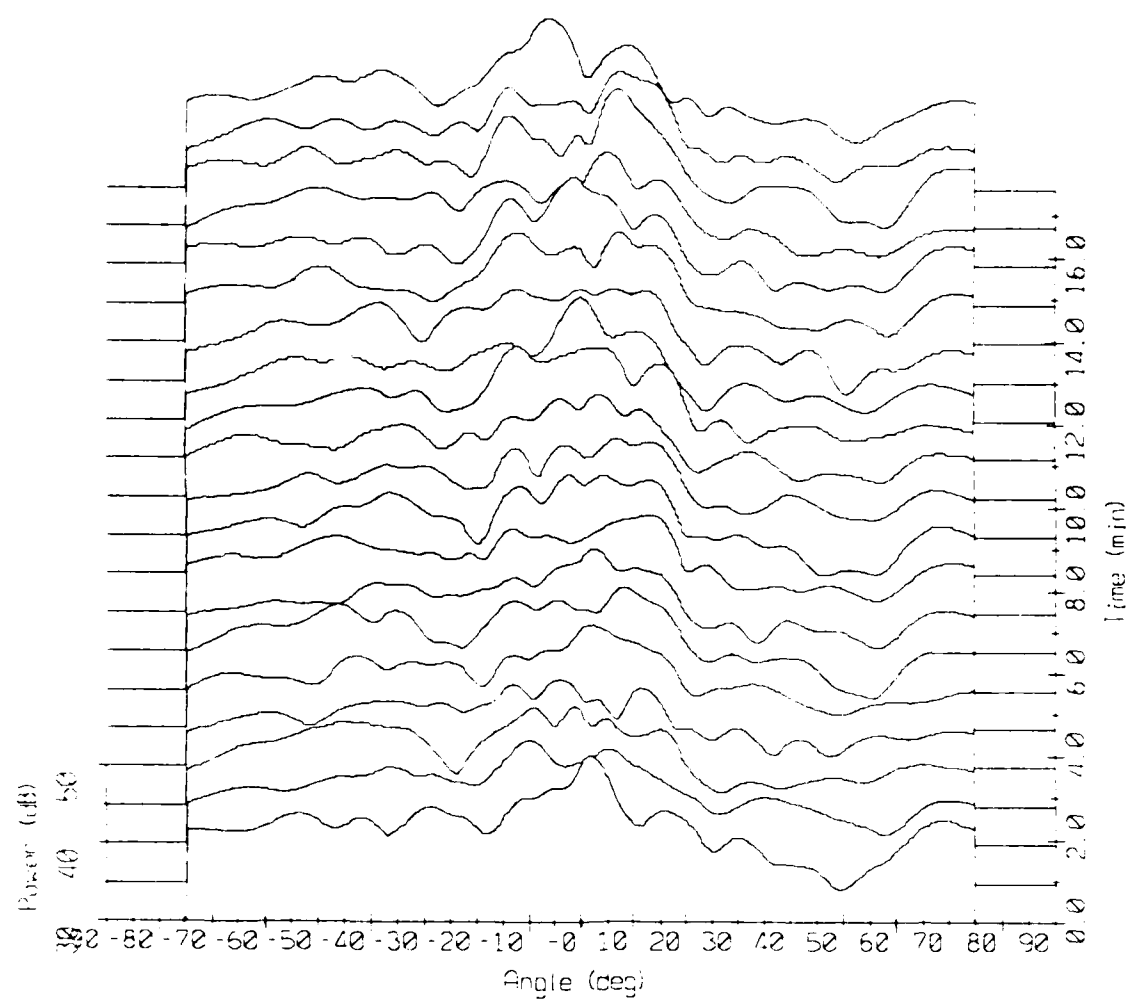
Array Response - 86247 Bin #5316
 $f = 175$ Hz, KB window ($\alpha = 1.5$)



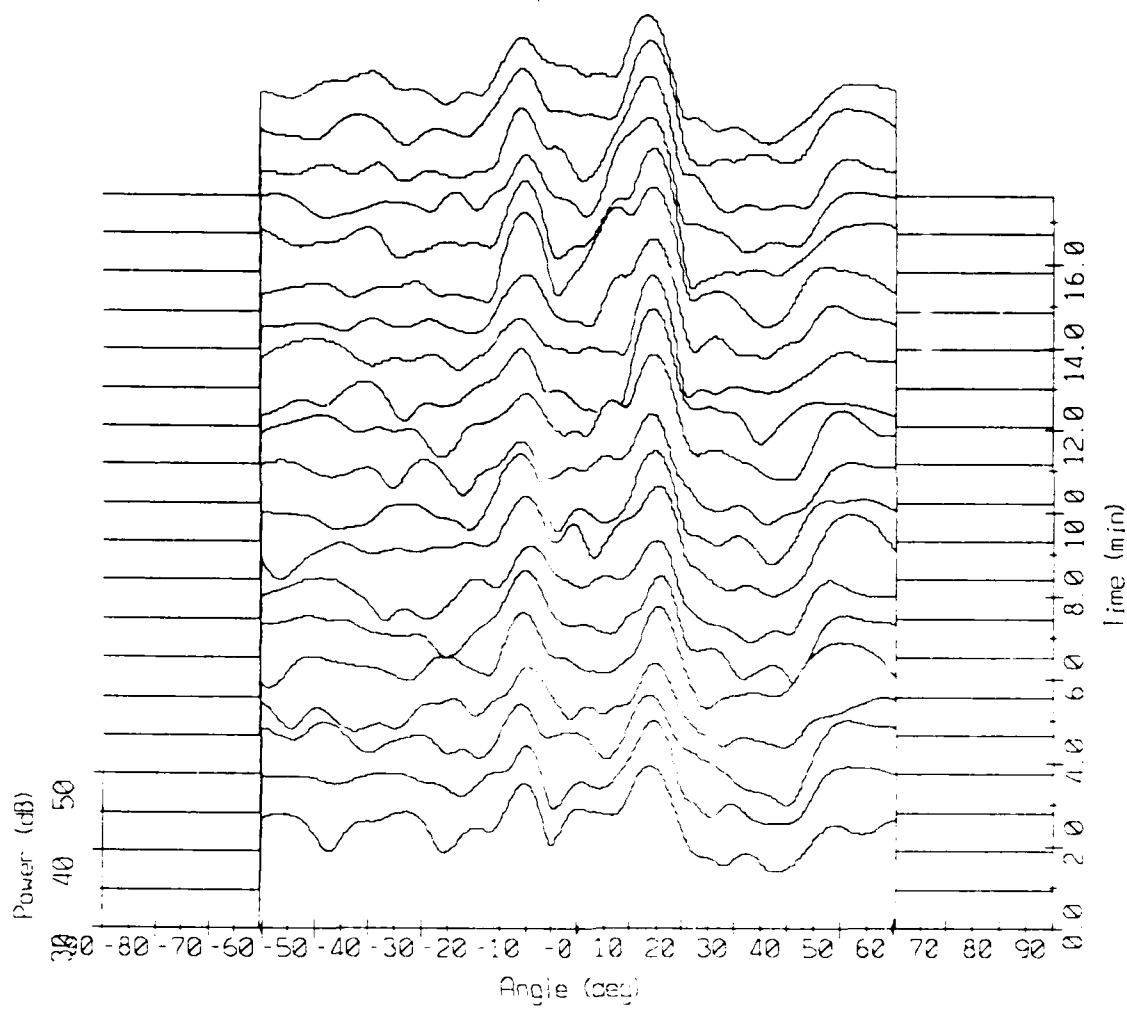
Array Response - 86247 Bin #5490
 $f = 200$ Hz, KB window ($\alpha = 1.5$)



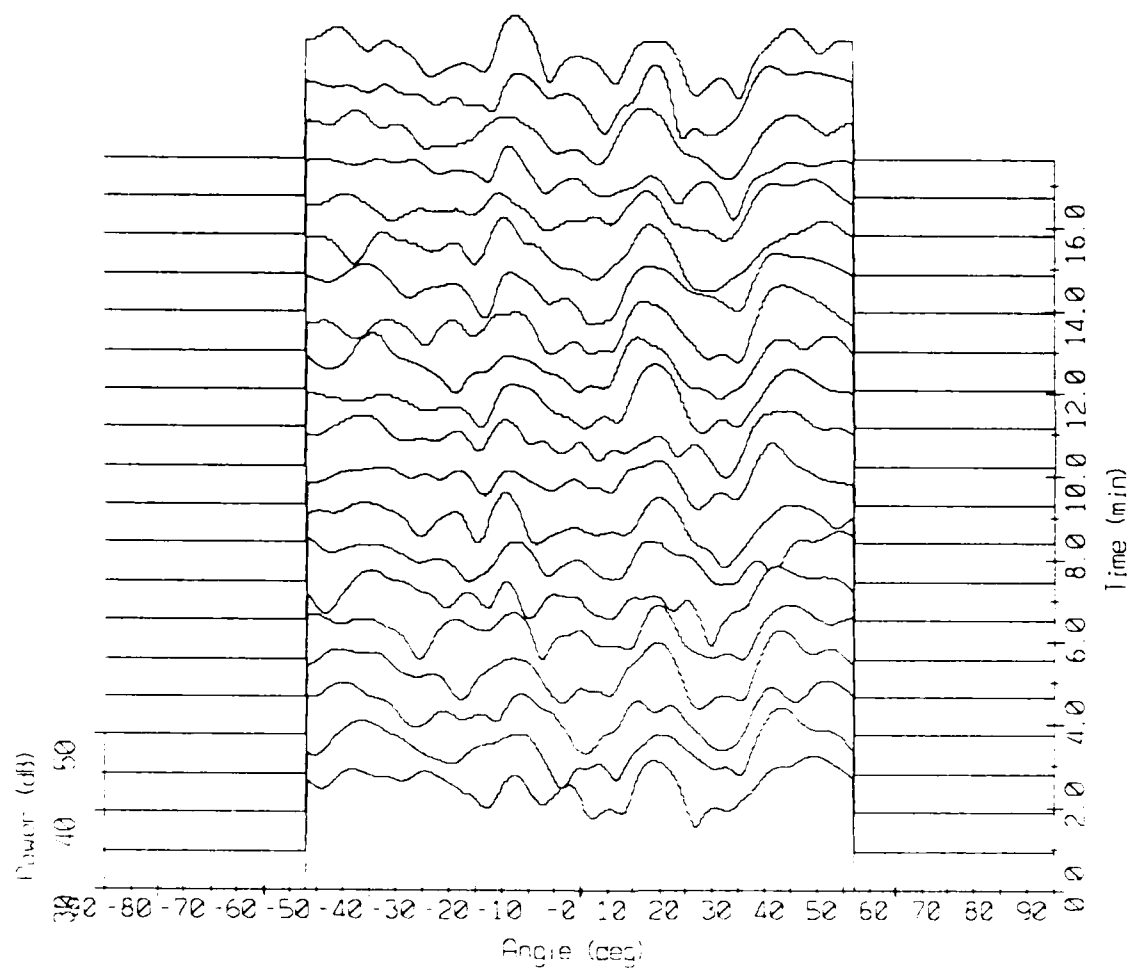
Array Response - 86247 Bin #5664
 $f = 225$ Hz, KB window ($\alpha = 1.5$)



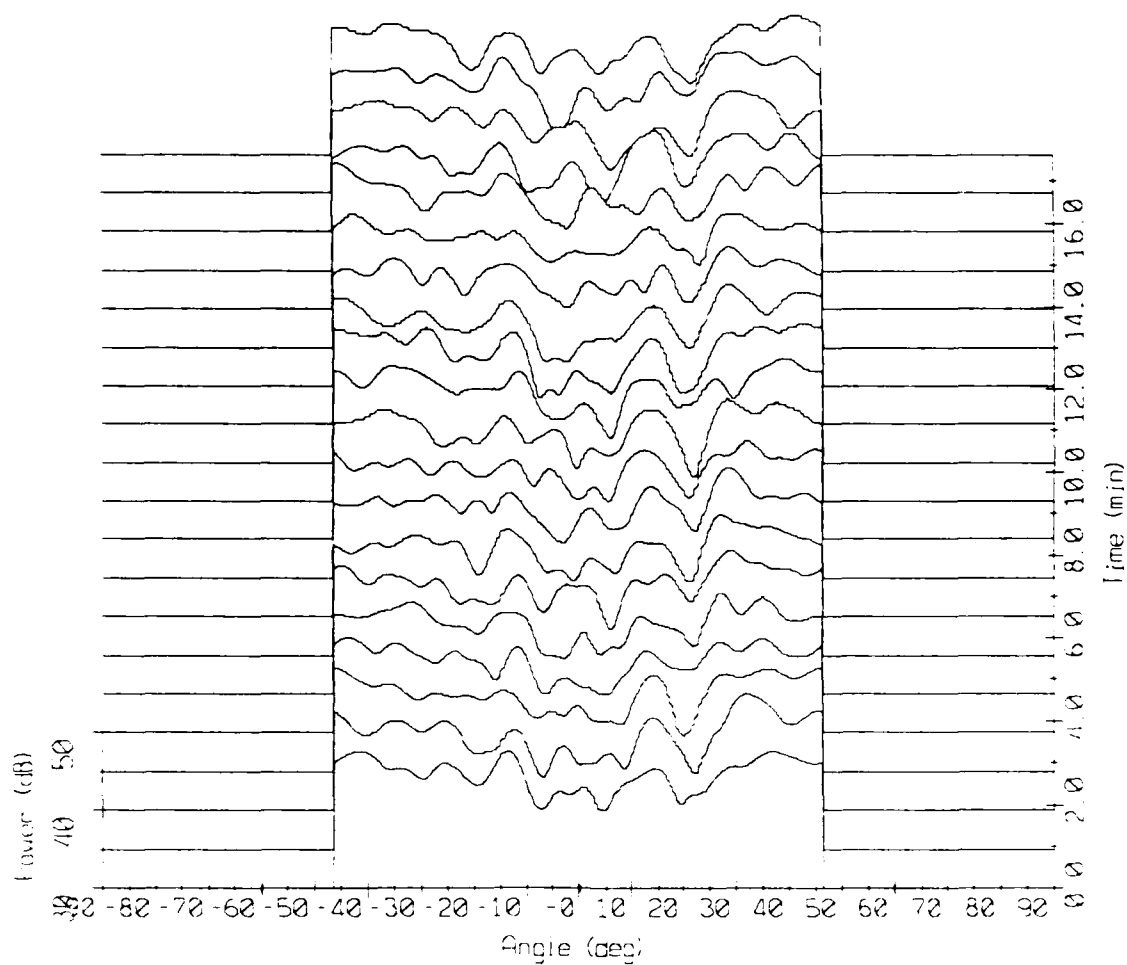
Array Response - 86247 Bin #5832
 $f = 250$ Hz, KB window ($\alpha_{phc} = 1.5$)



Array Response - 86247 Bin #6012
 $f = 275$ Hz, KB window ($\alpha = 1.5$)

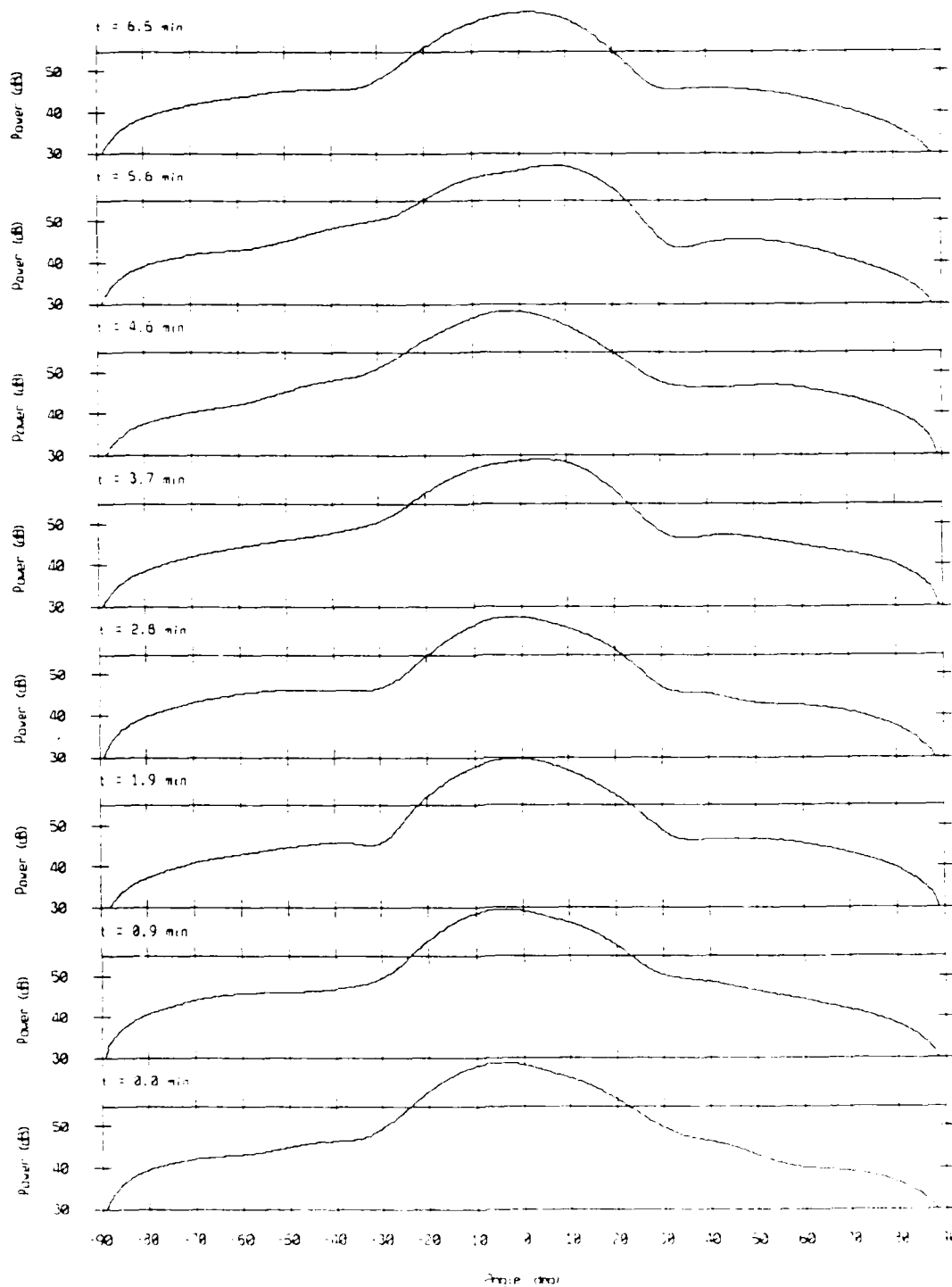


Array Response - 86247 Bin #6186
 $f = 300$ Hz, KB window ($\alpha = 1.5$)



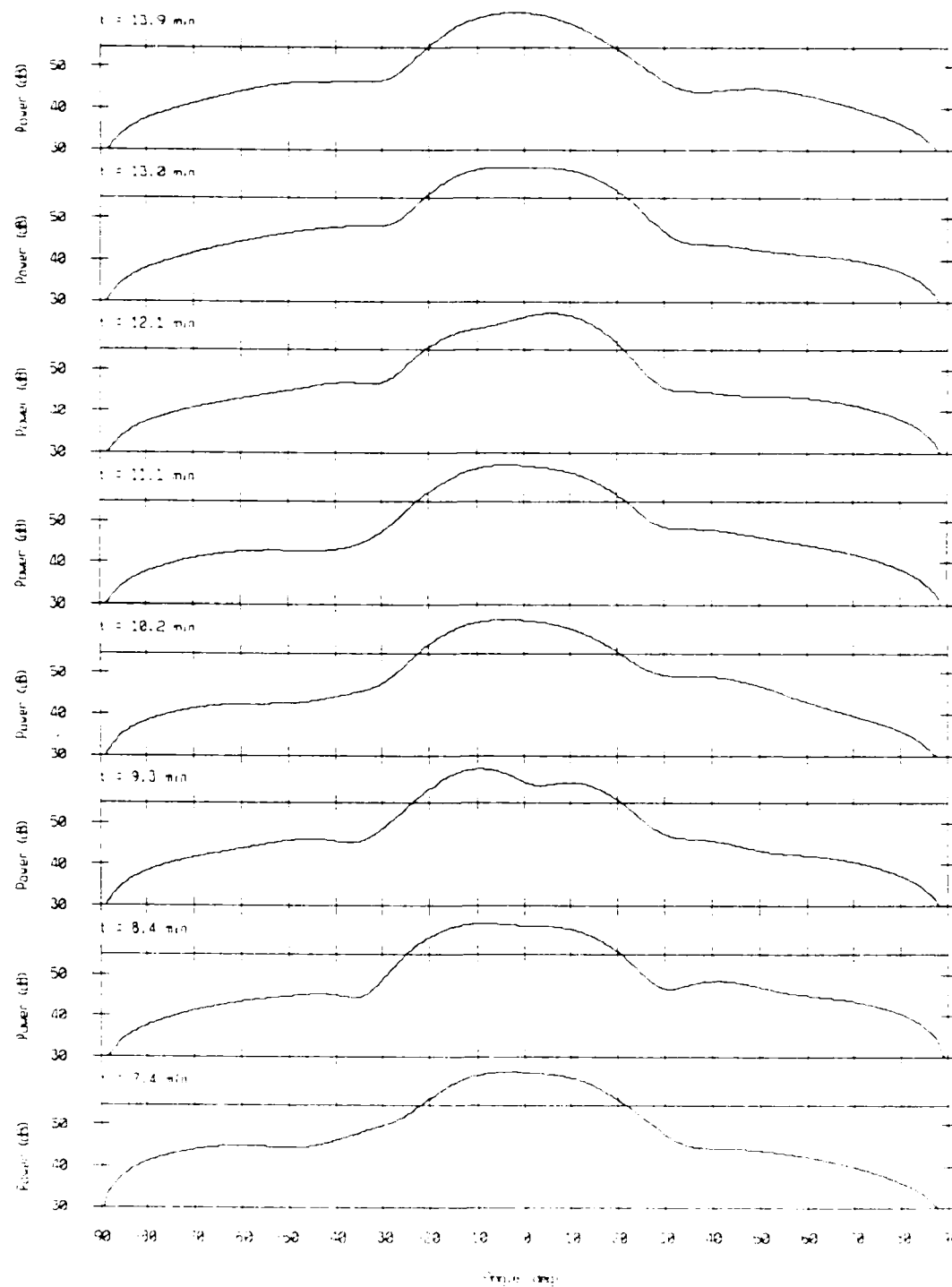
Array Response - 86247 Bin #4619

$f = 75$ Hz, KB window ($\alpha = 1.5$)



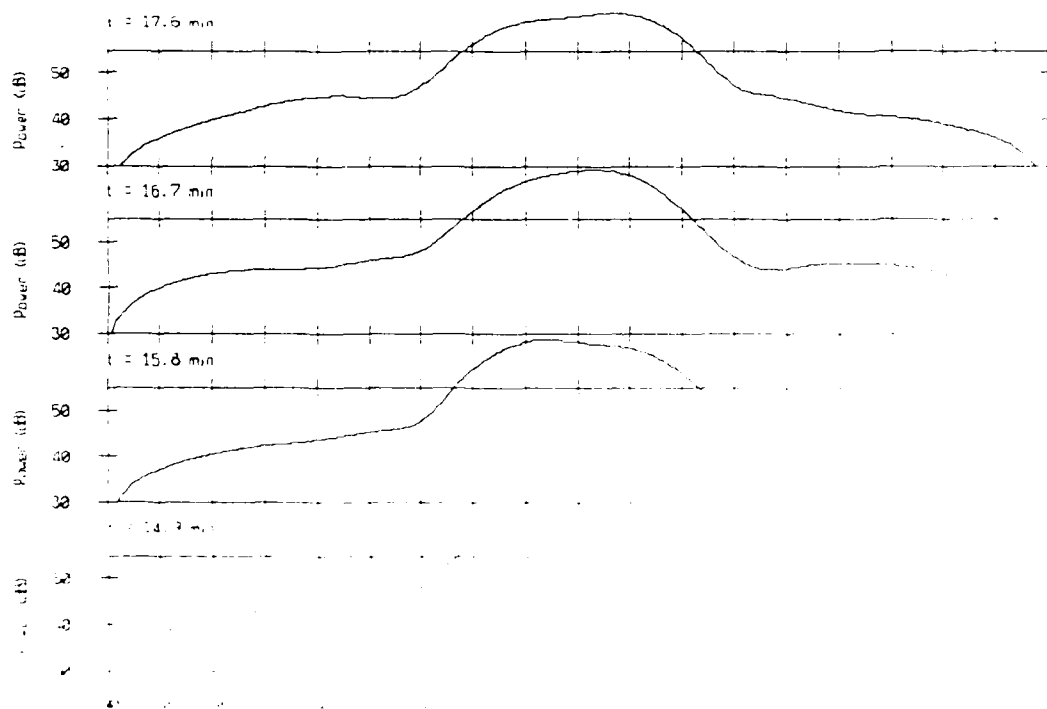
Array Response - 86247 Bin #4619

$f = 75$ Hz, ΔB window (alpha = 1.5)



Array Response - 86247 Bin #4619

$f = 75$ Hz, K3 window (alpha = 1.5)



AD-A193 232

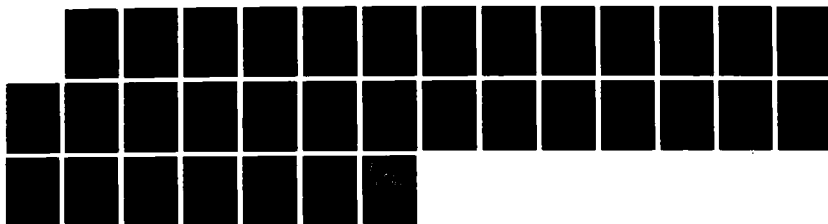
VERTICAL DIRECTIONALITY OF AMBIENT NOISE AT 32 DEG N AS 2/2
A FUNCTION OF LON. (U) SCRIPPS INSTITUTION OF
OCEANOGRAPHY LA JOLLA CA MARINE PHYSIC.

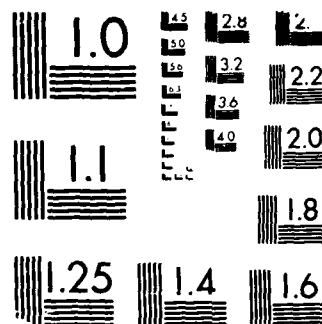
UNCLASSIFIED

W S HODGKISS ET AL. JAN 88 MPL-TM-387-A

F/G 20/1

NL

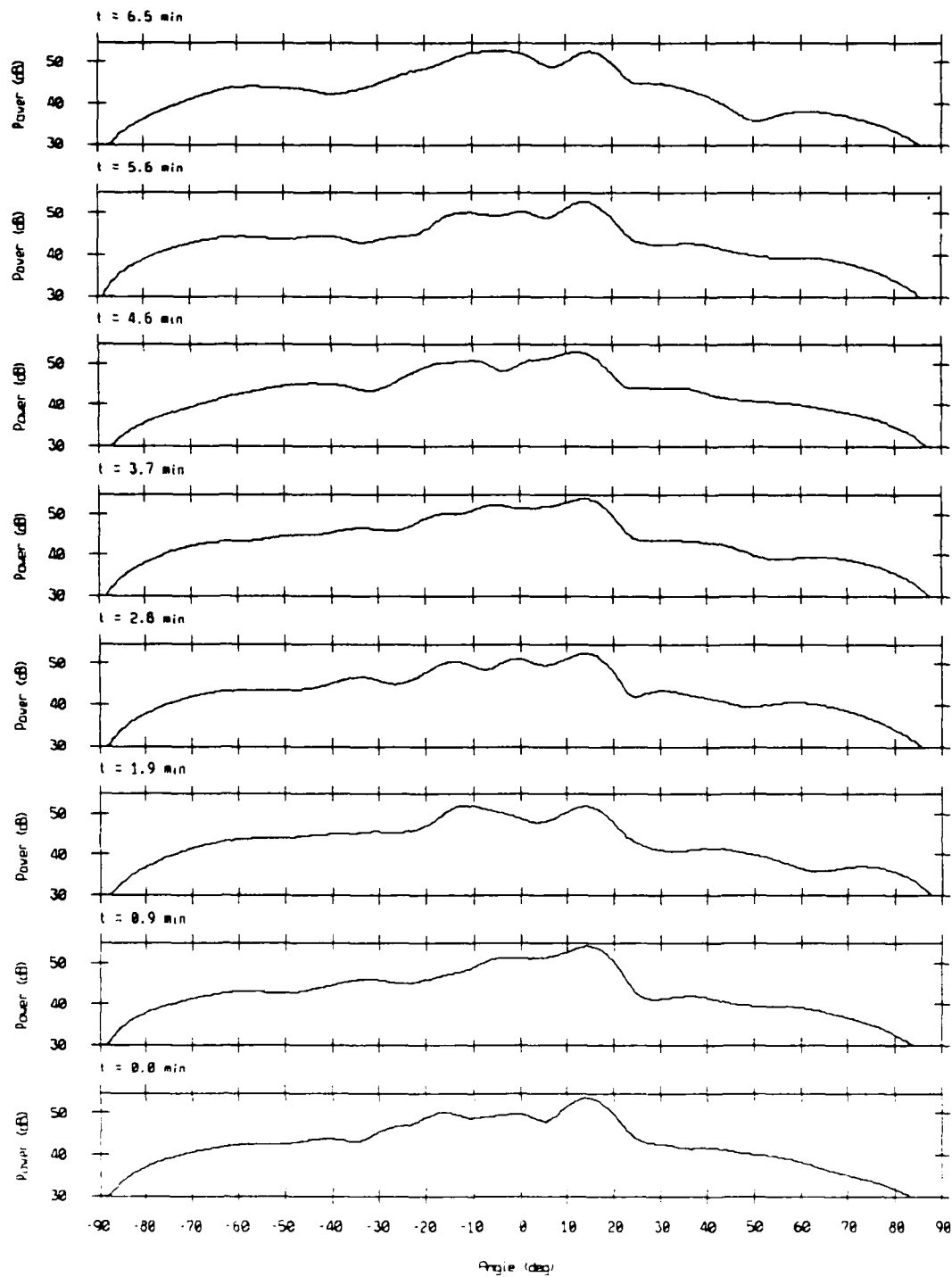




MICROCOPY RESOLUTION TEST CHART
1963-A

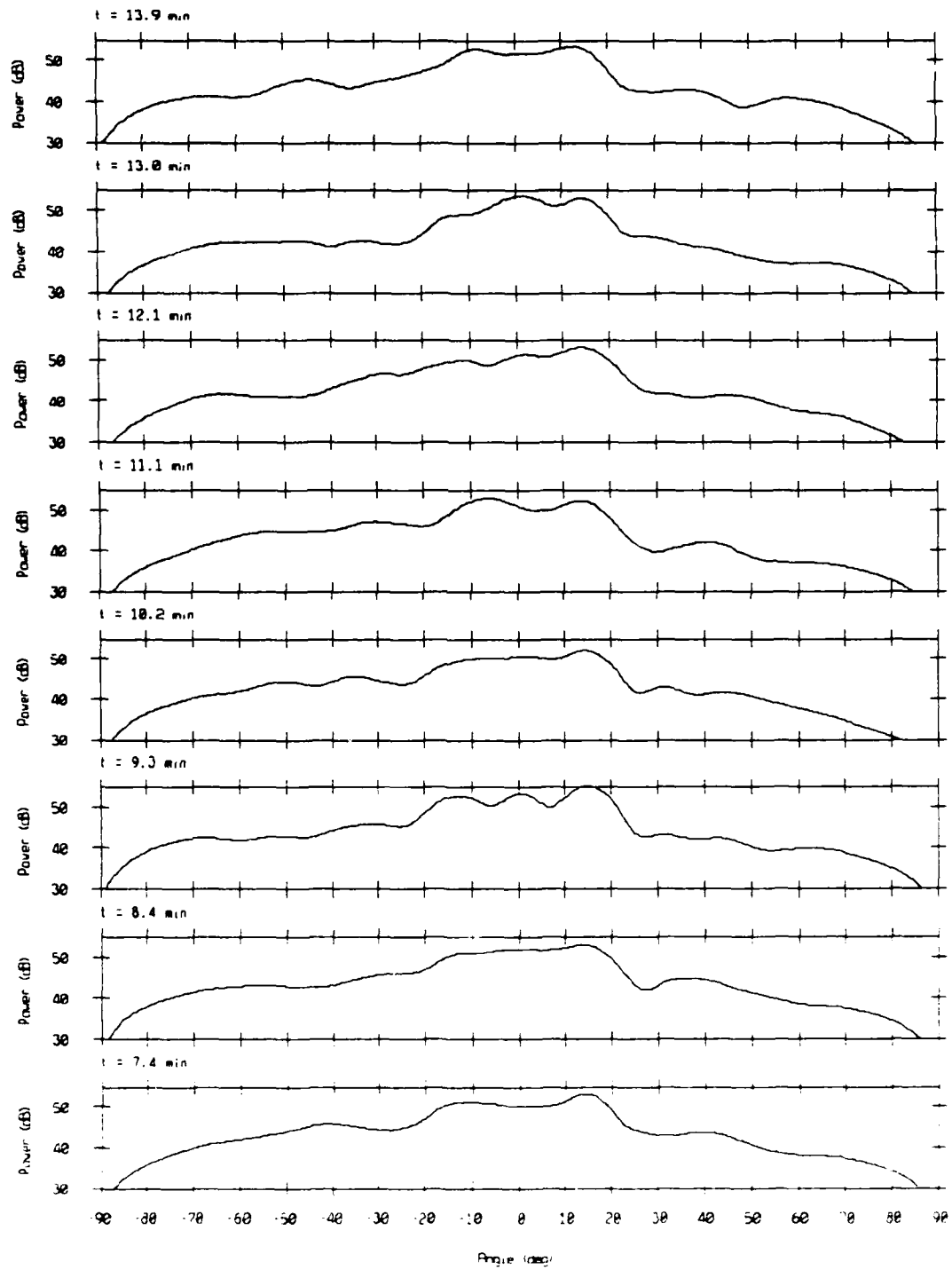
Array Response - 86247 Bin #5141

$f = 150$ Hz, KB window ($\alpha = 1.5$)



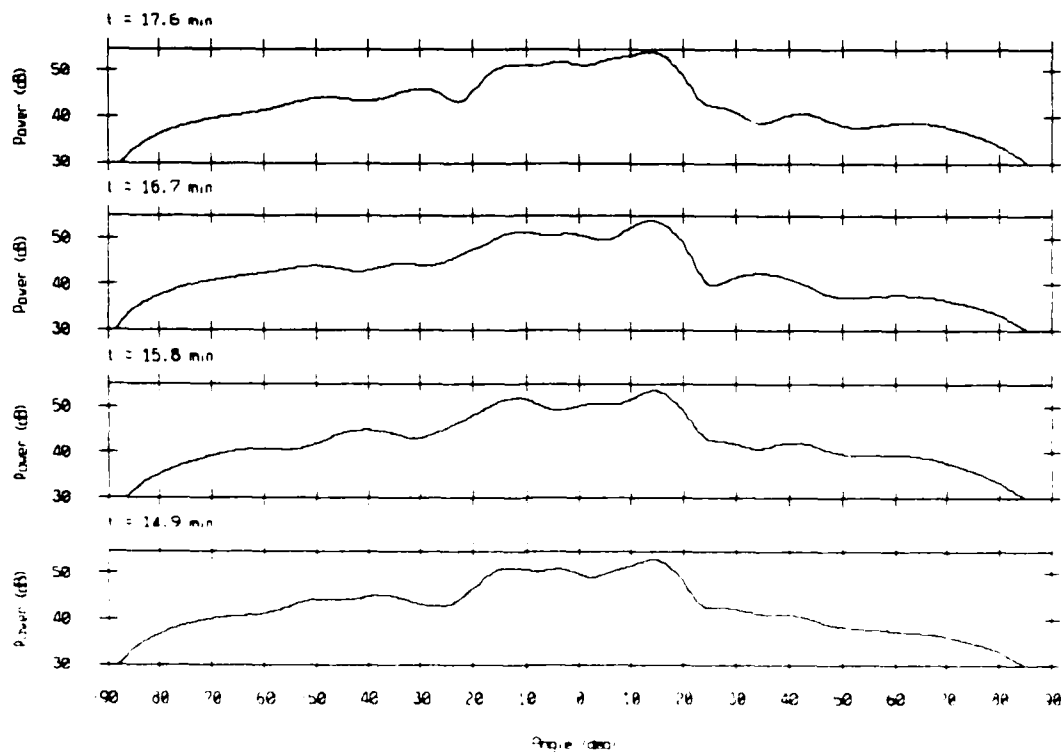
Array Response - 86247 Bin #5141

$f = 150 \text{ Hz}$, KB window ($\alpha = 1.5$)

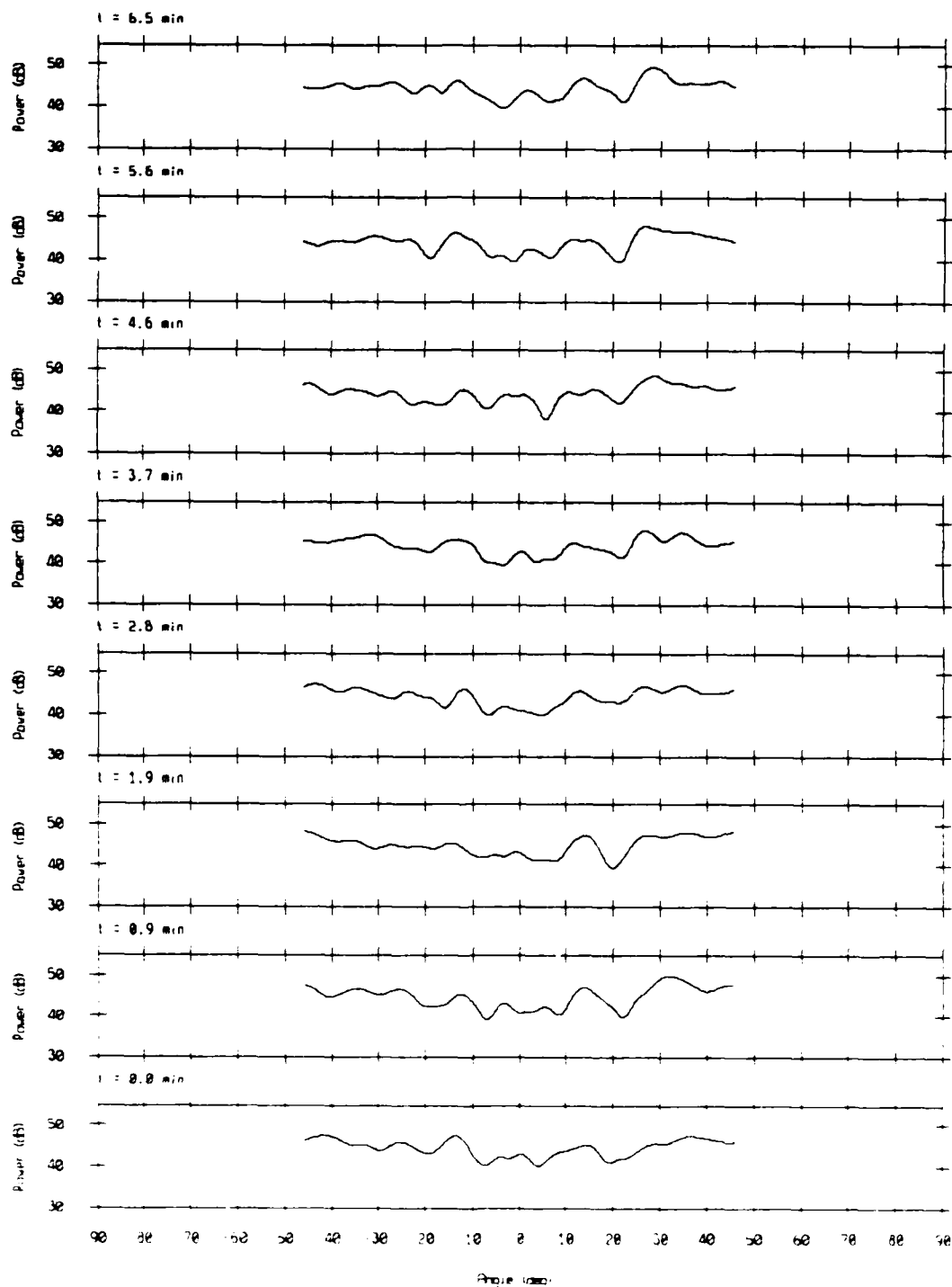


Array Response - 86247 Bin #5141

$f = 150$ Hz, KB window ($\alpha = 1.5$)

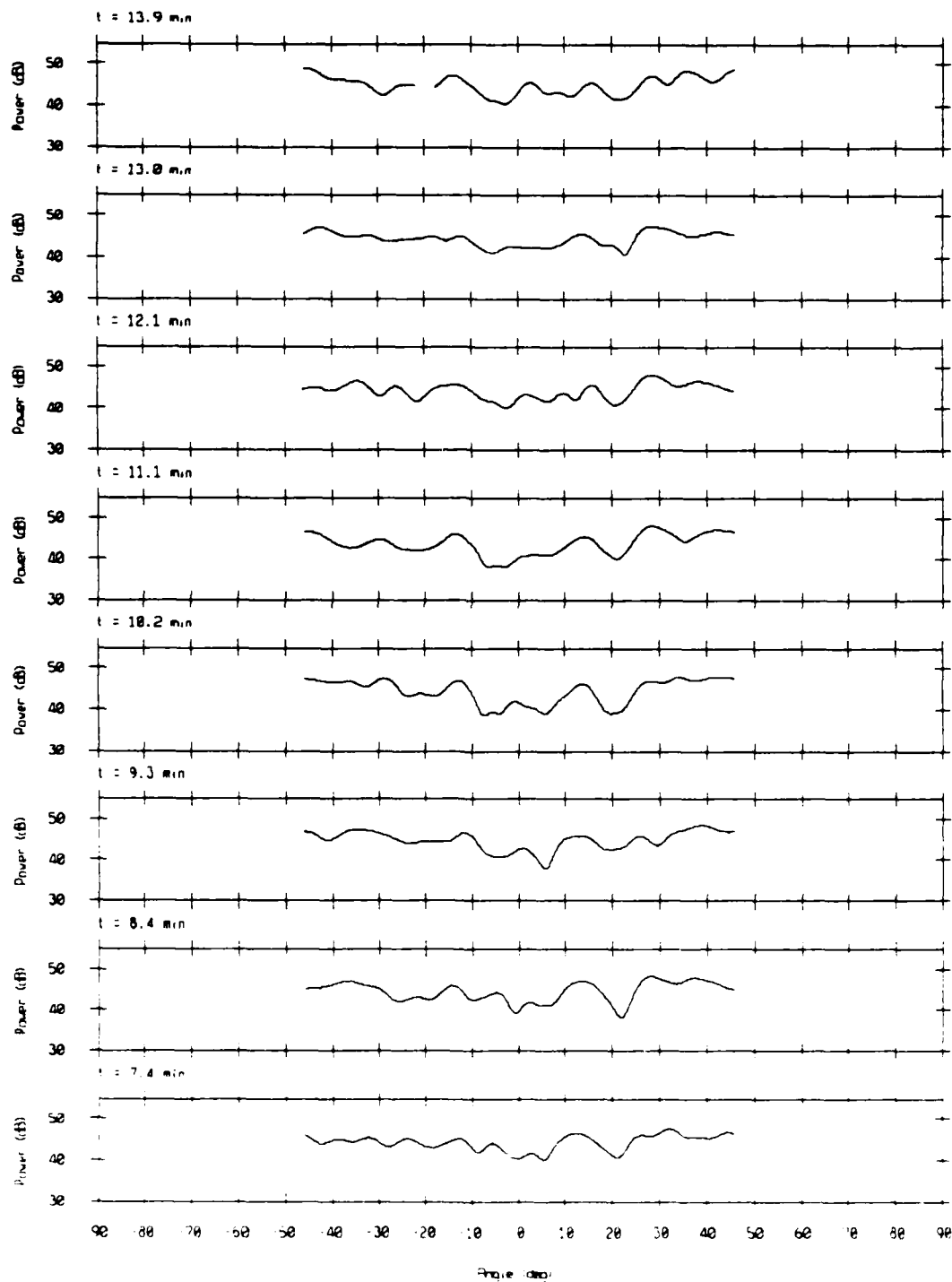


Array Response - 86247 Bin #6186
 $f = 300$ Hz, KB window ($\alpha = 1.5$)

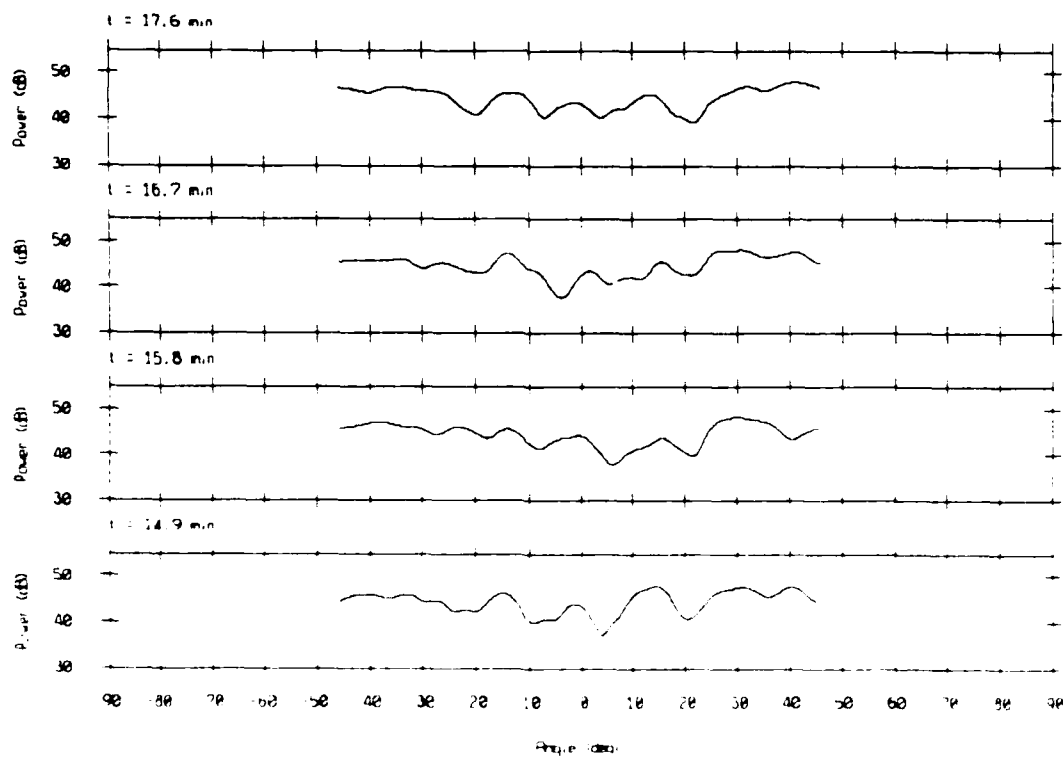


Array Response - 86247 Bin #6186

$f = 300$ Hz, KB window ($\alpha = 1.5$)



Array Response - 86247 Bin #6186
 $f = 300$ Hz, KB window ($\alpha = 1.5$)



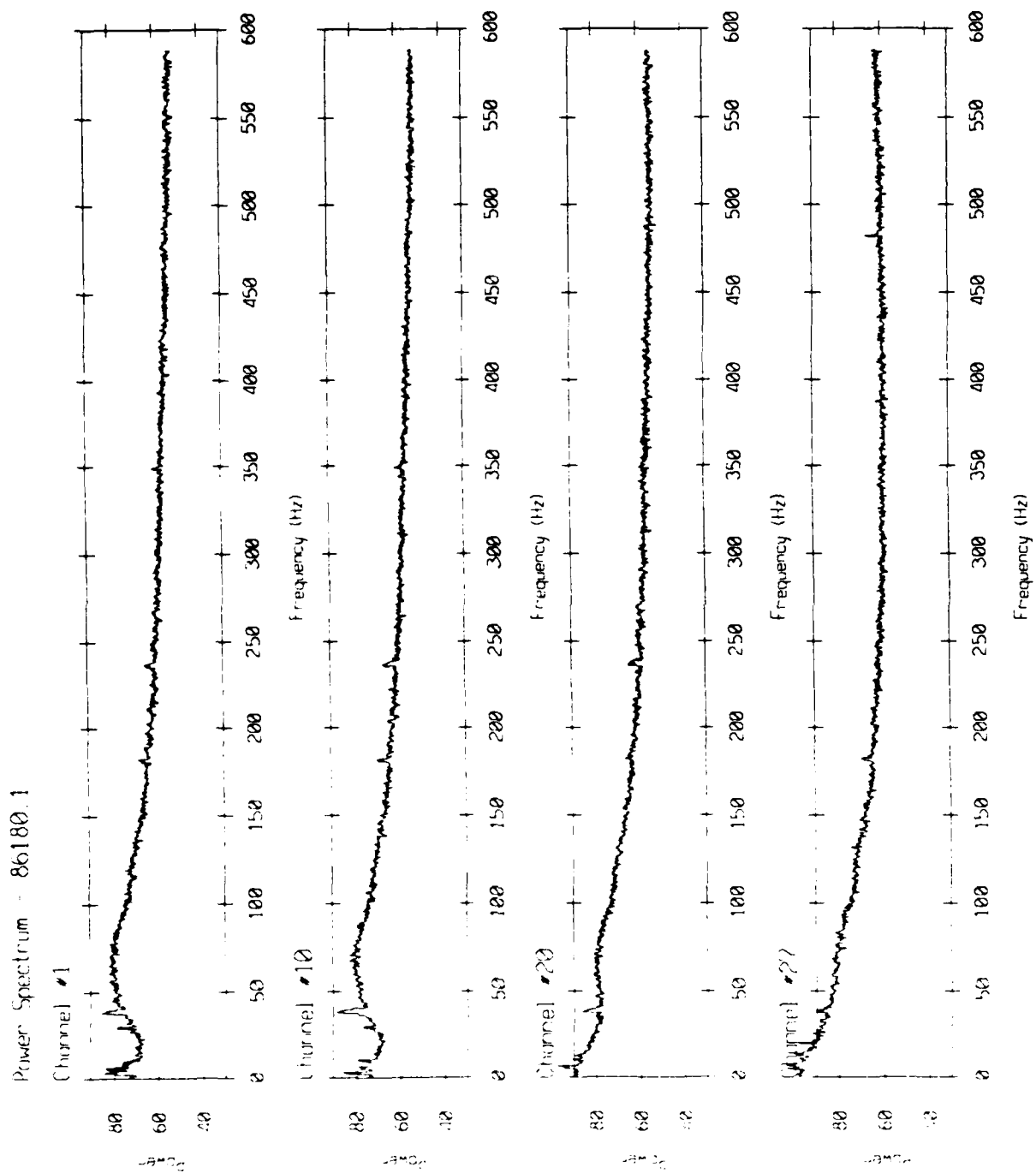


Figure 17.

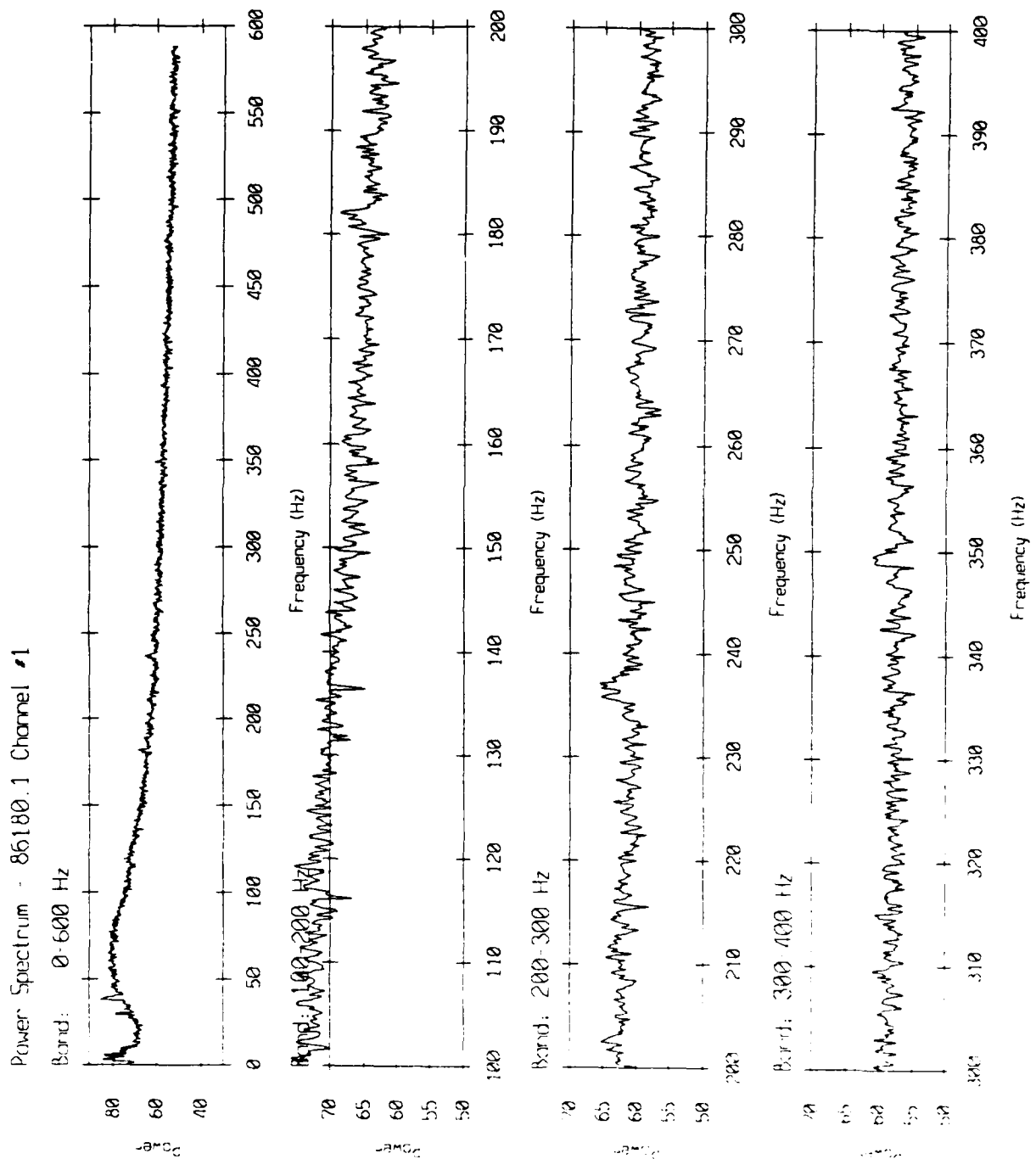


Figure 18(a).

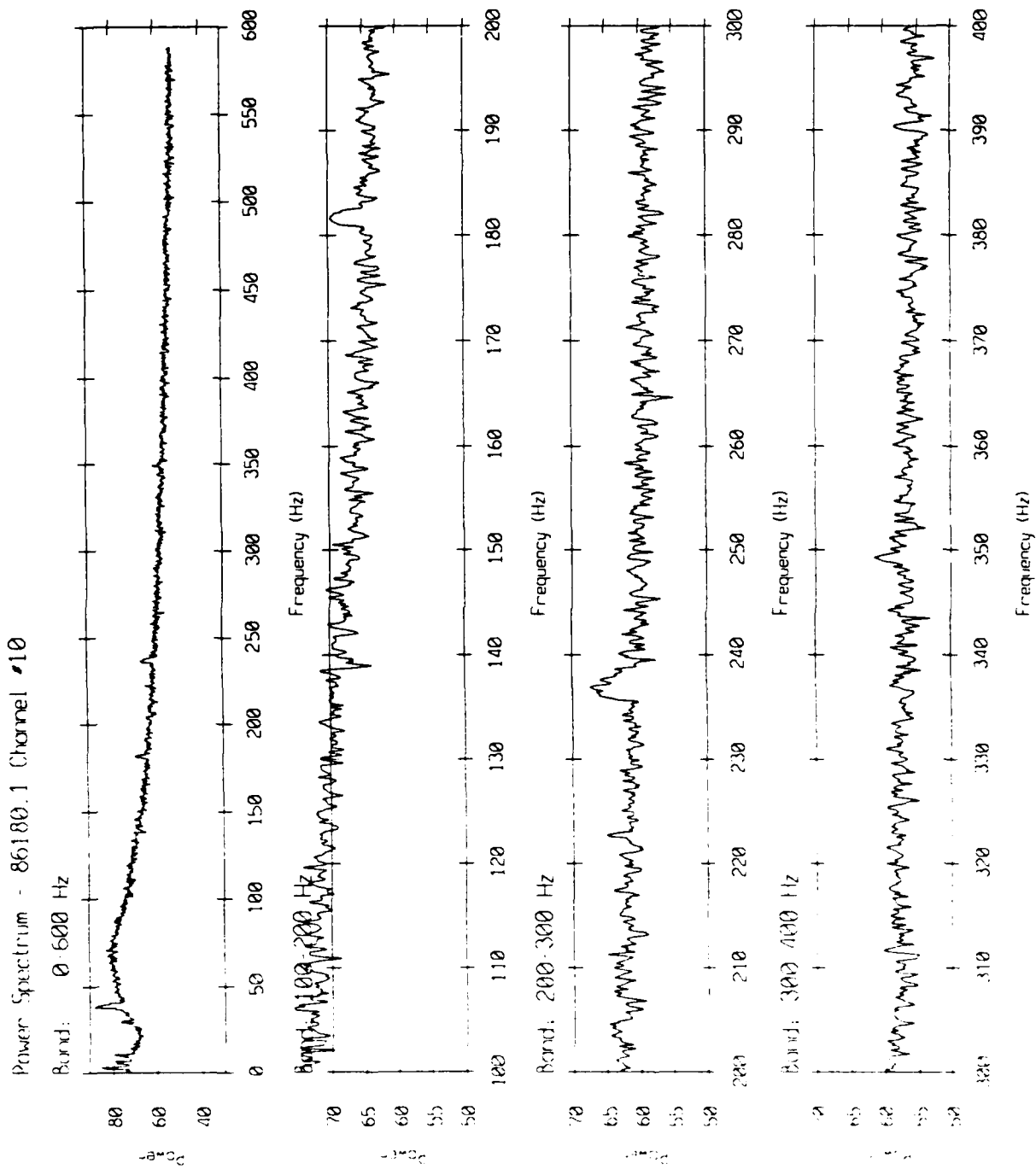


Figure 18(b).

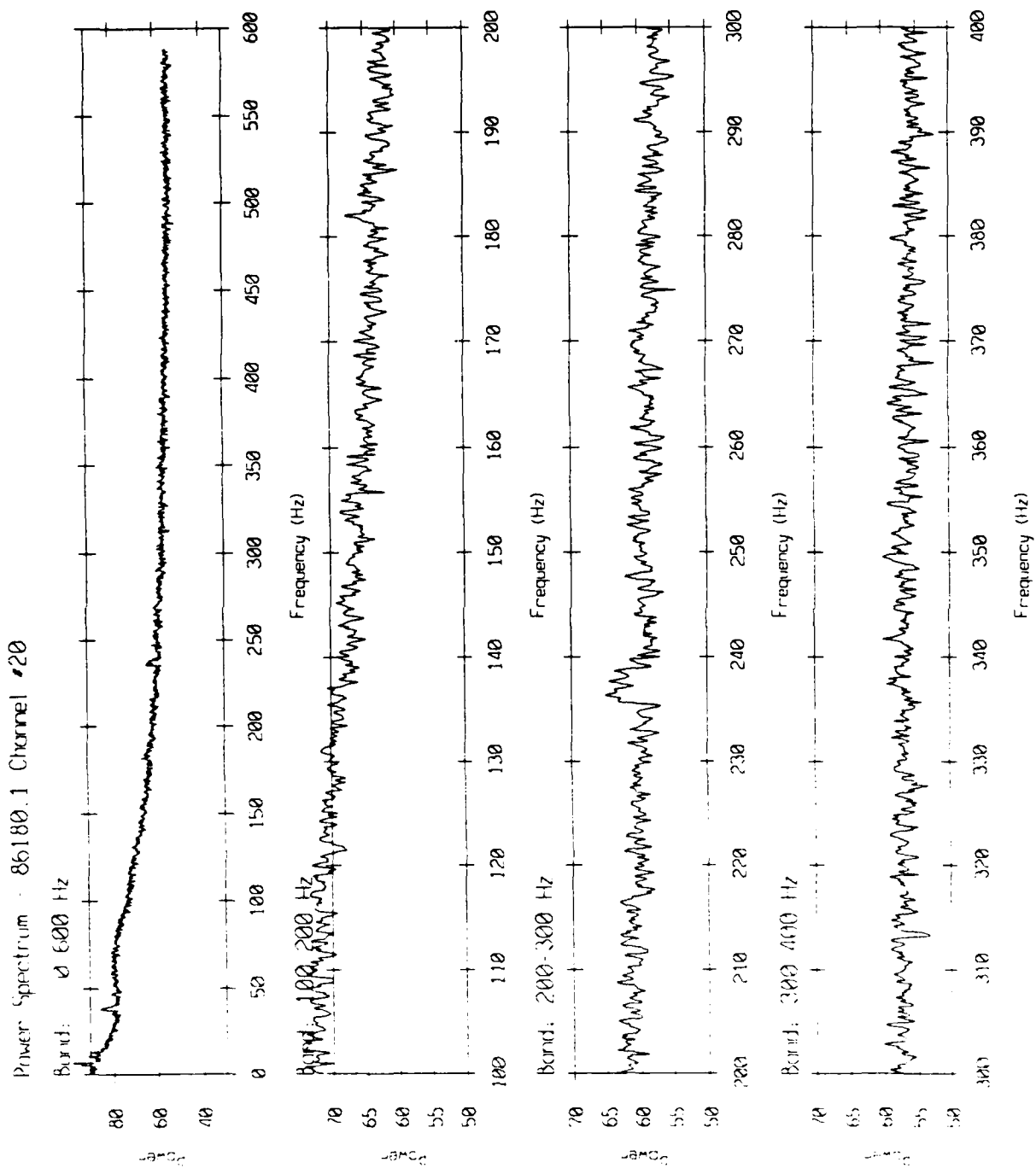


Figure 1d(c).

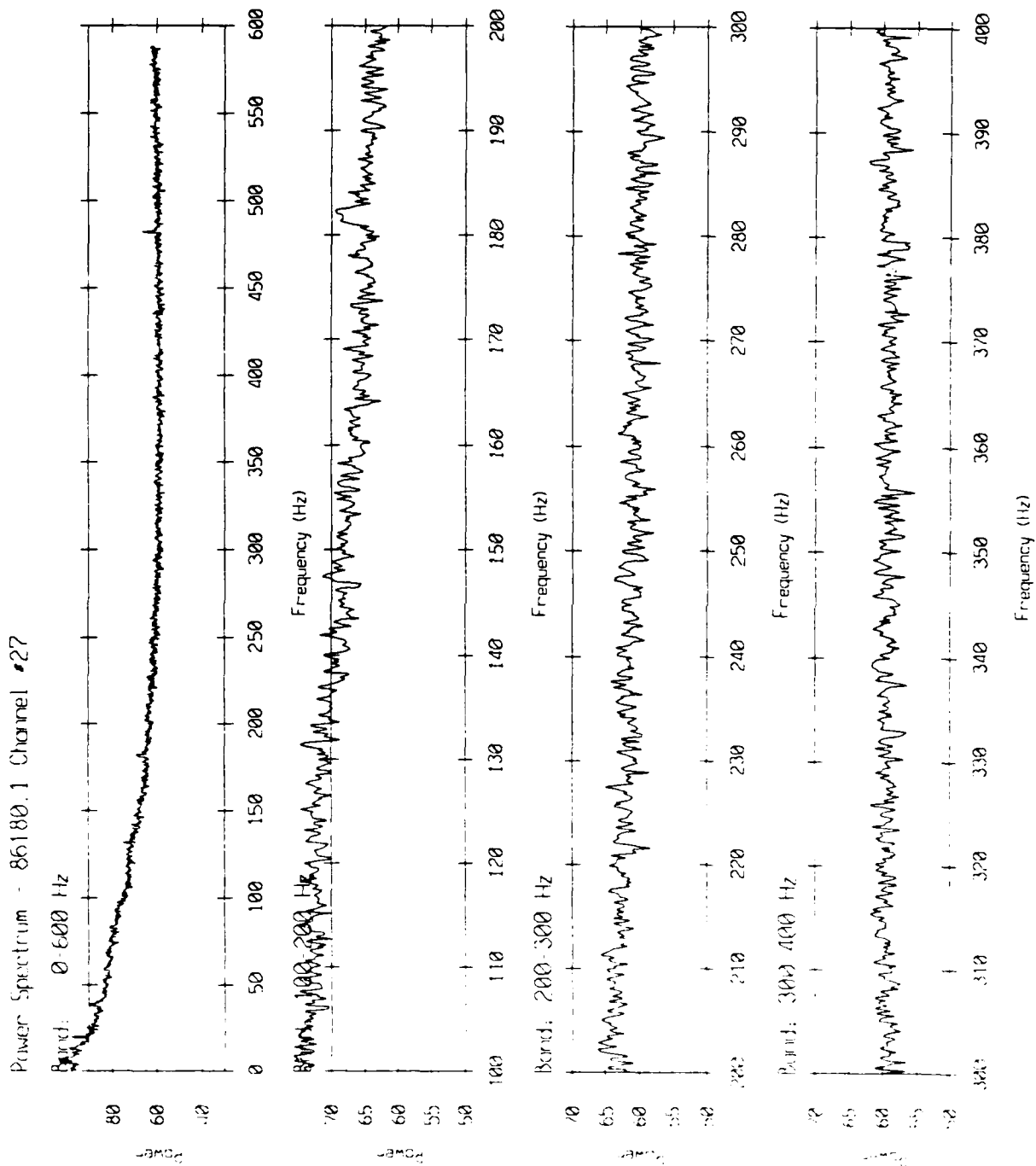
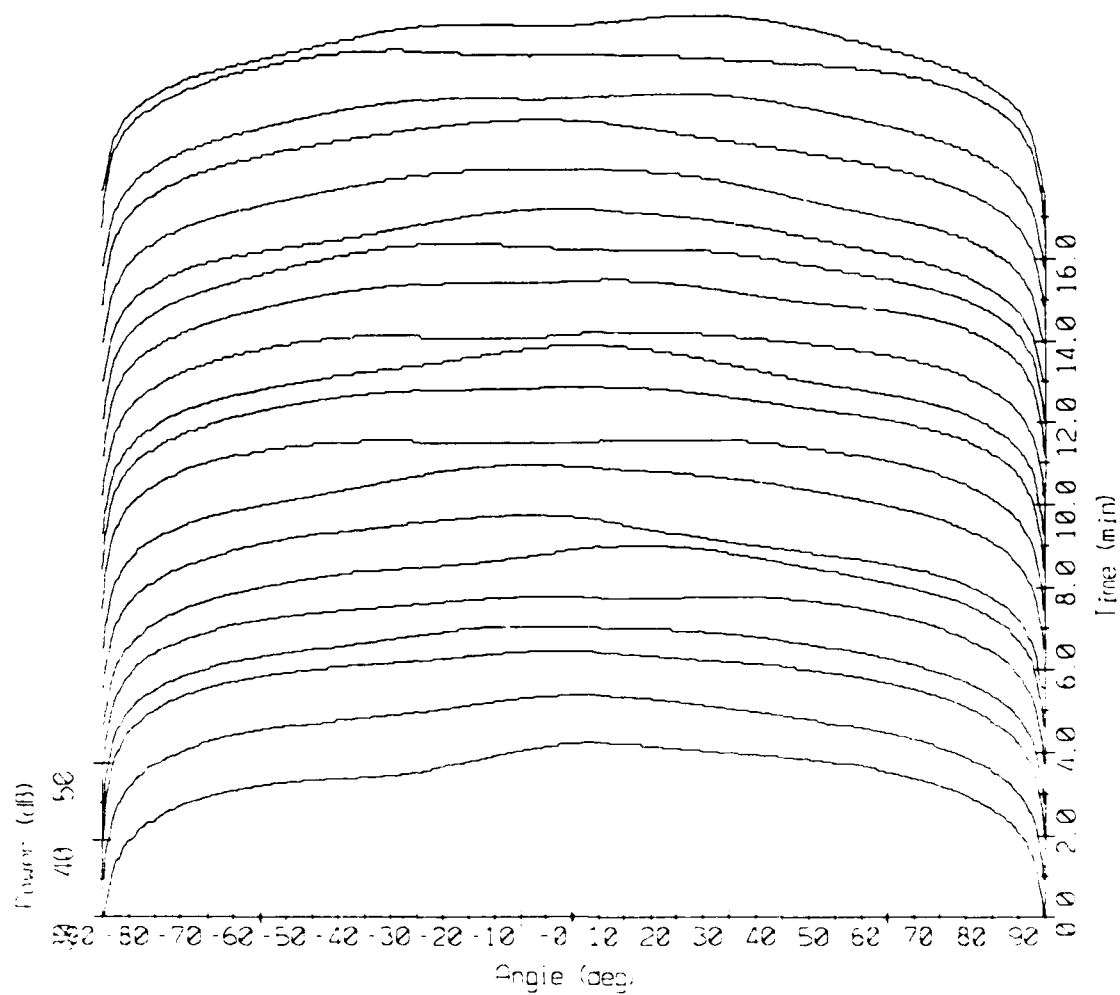
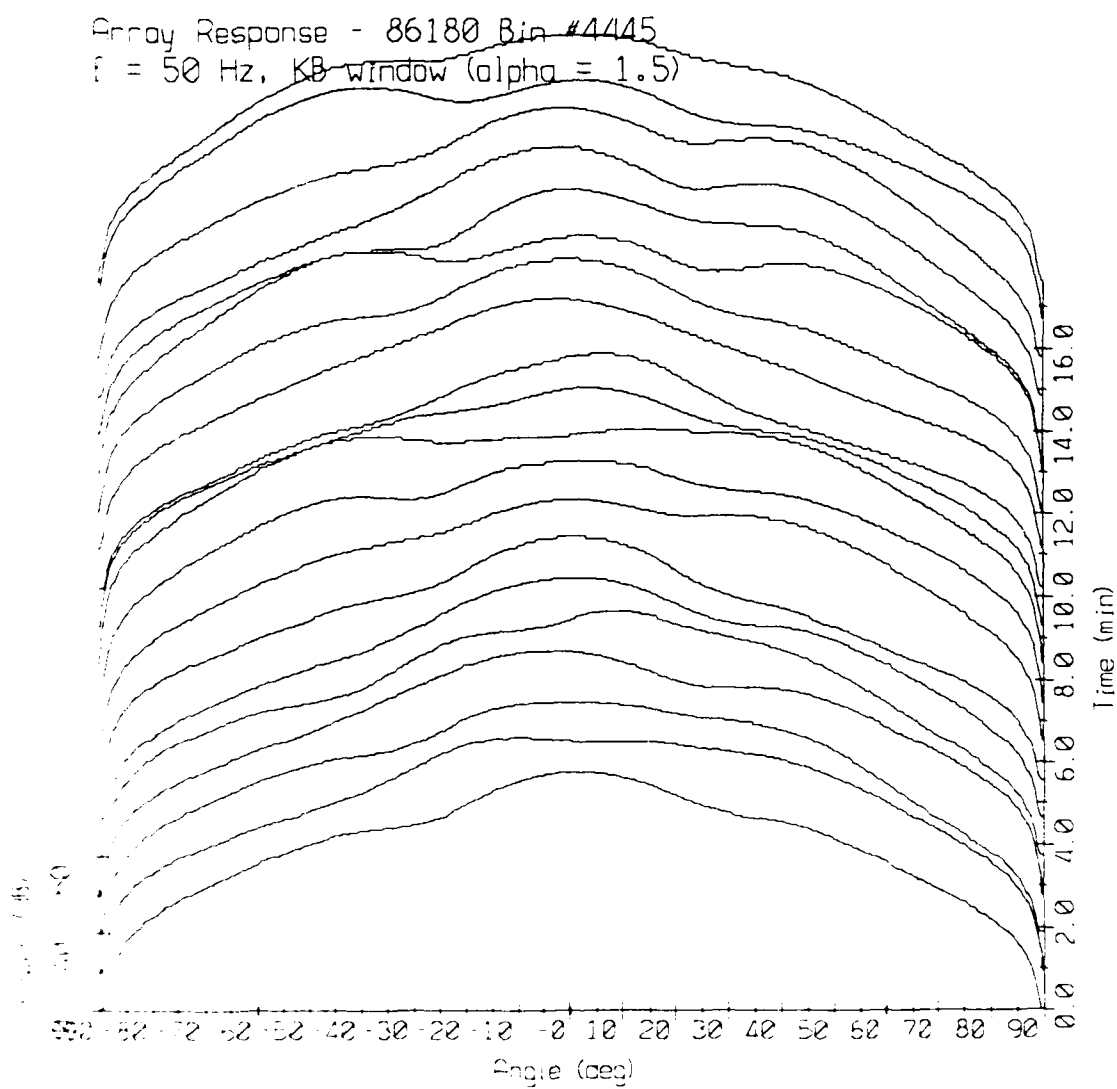
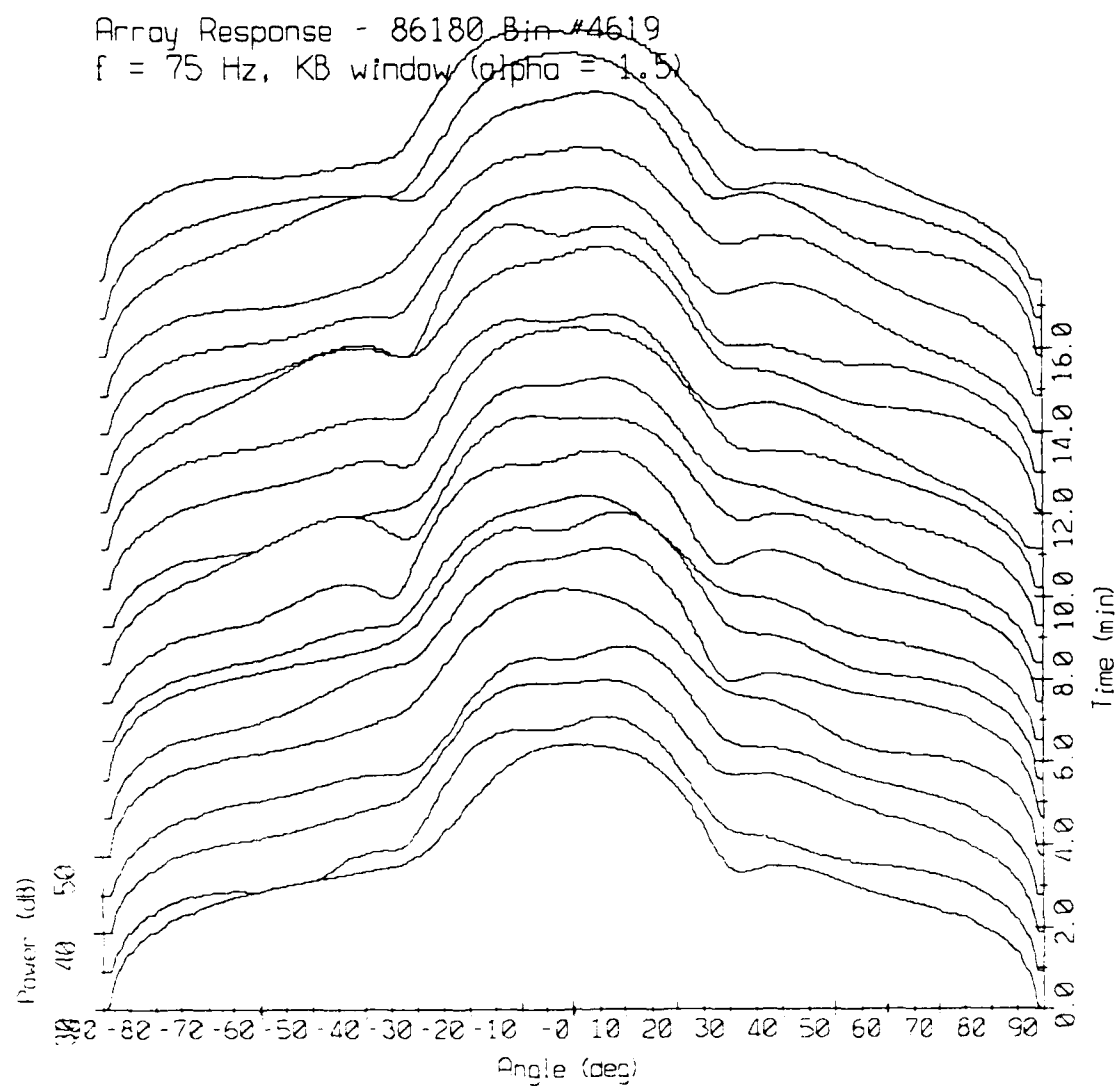


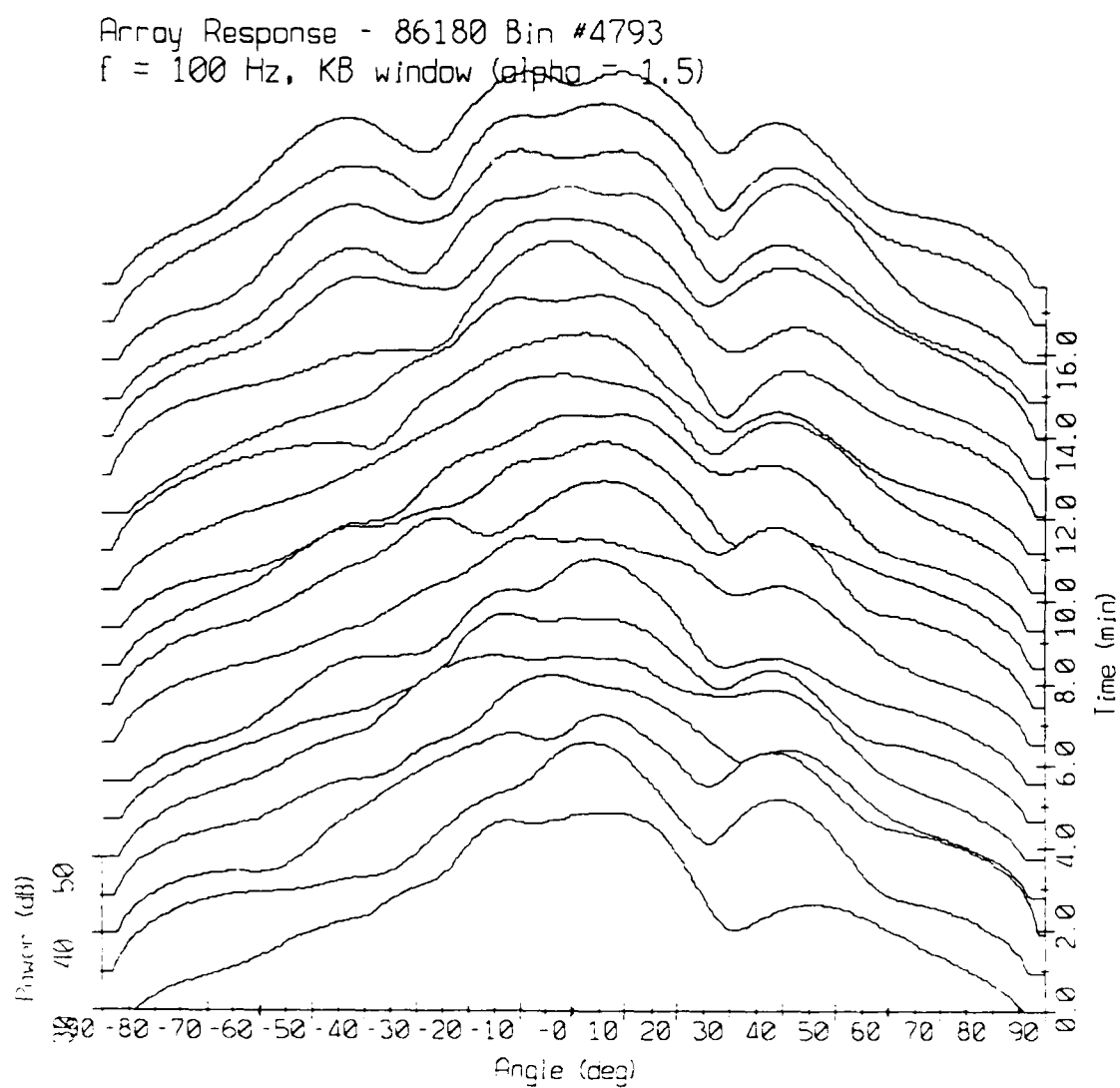
Figure 18(d).

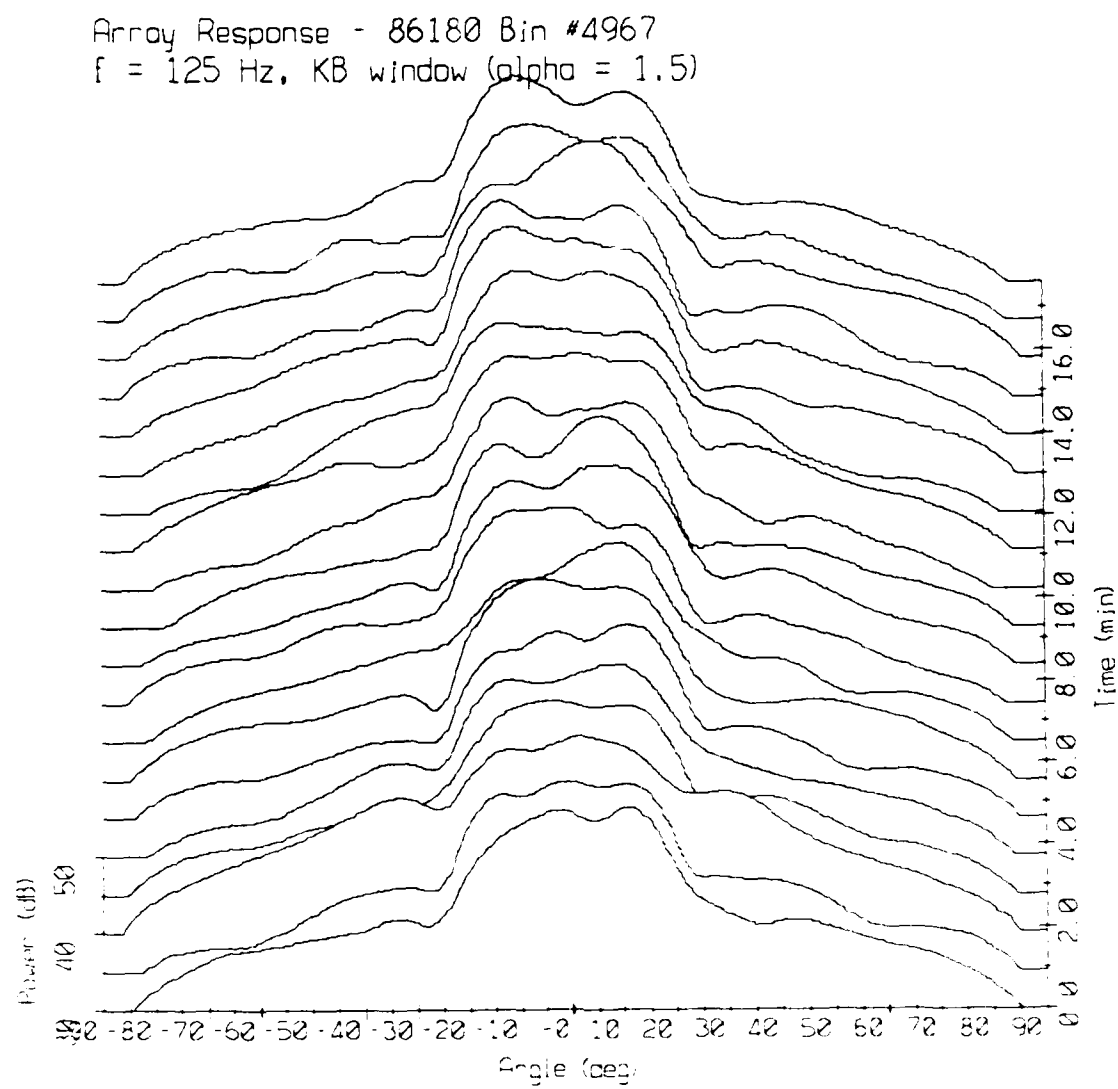
Array Response - 86180 Bin #4271
 $f = 25$ Hz, KB window ($\alpha = 1.5$)



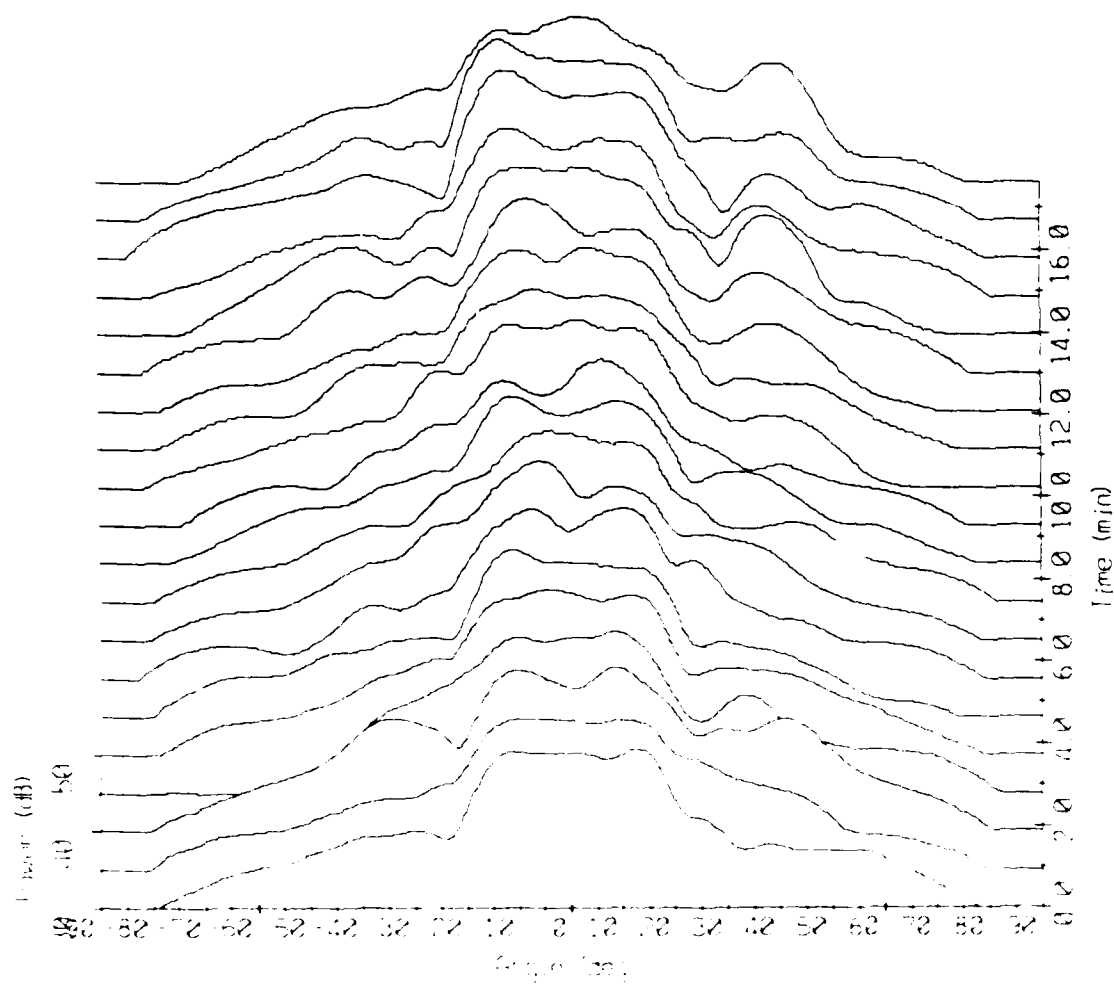




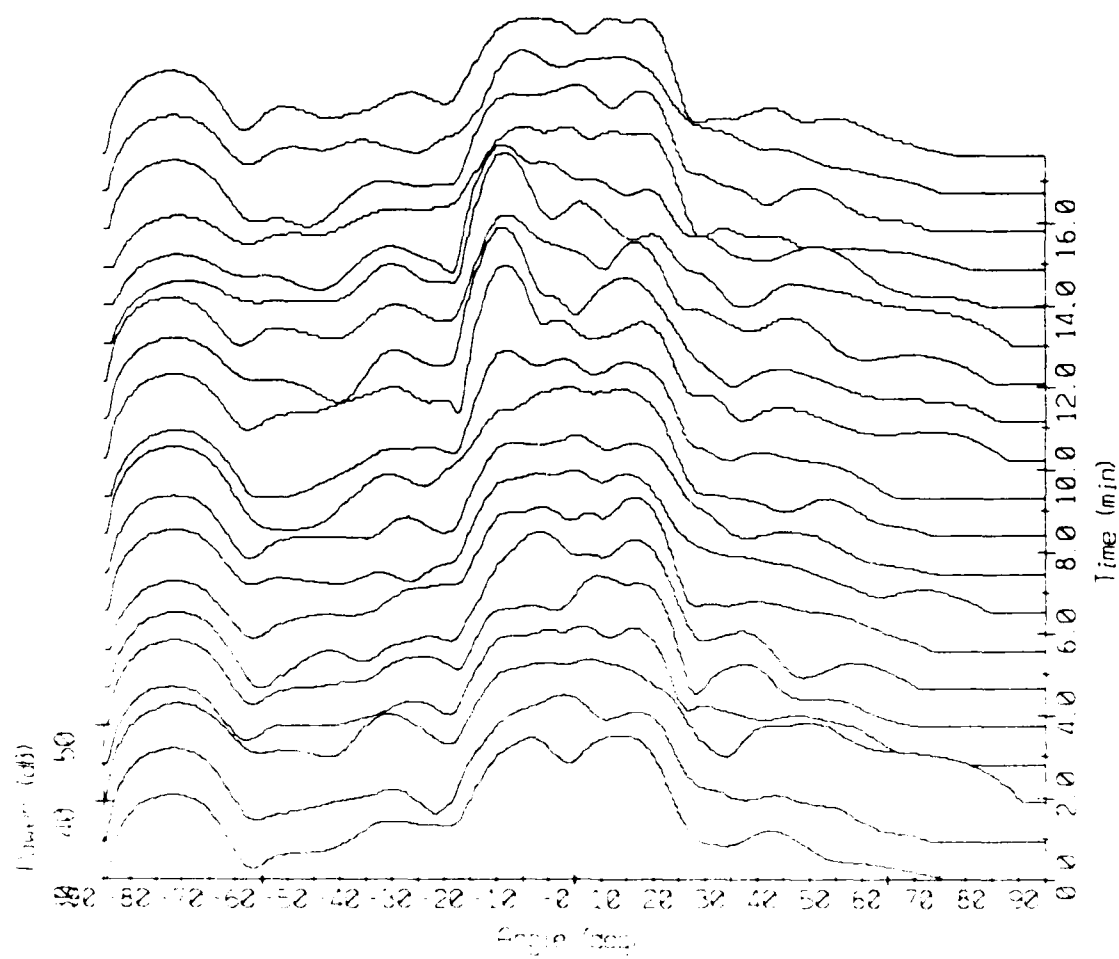




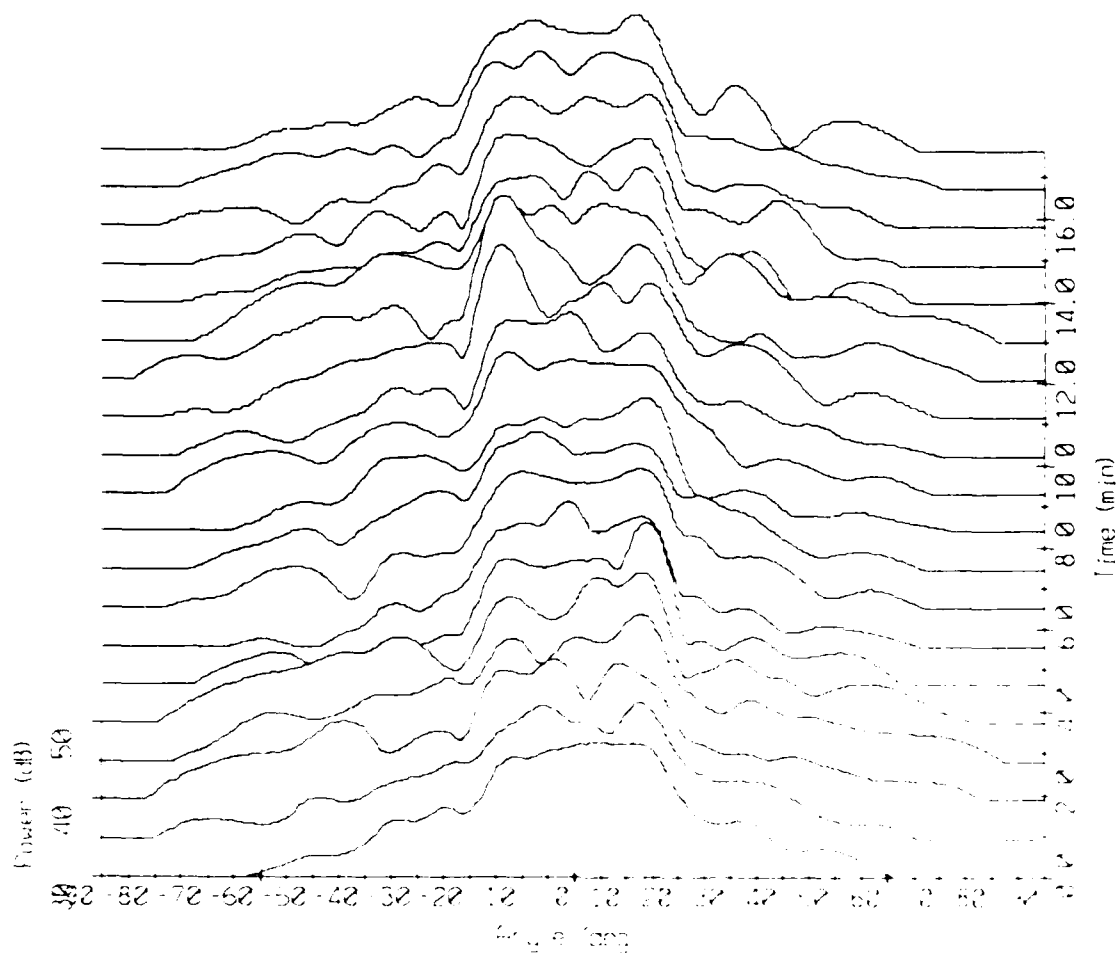
Array Response - 86180 Bin #5141
 $f = 150$ Hz, KB window ($\alpha = 1.5$)



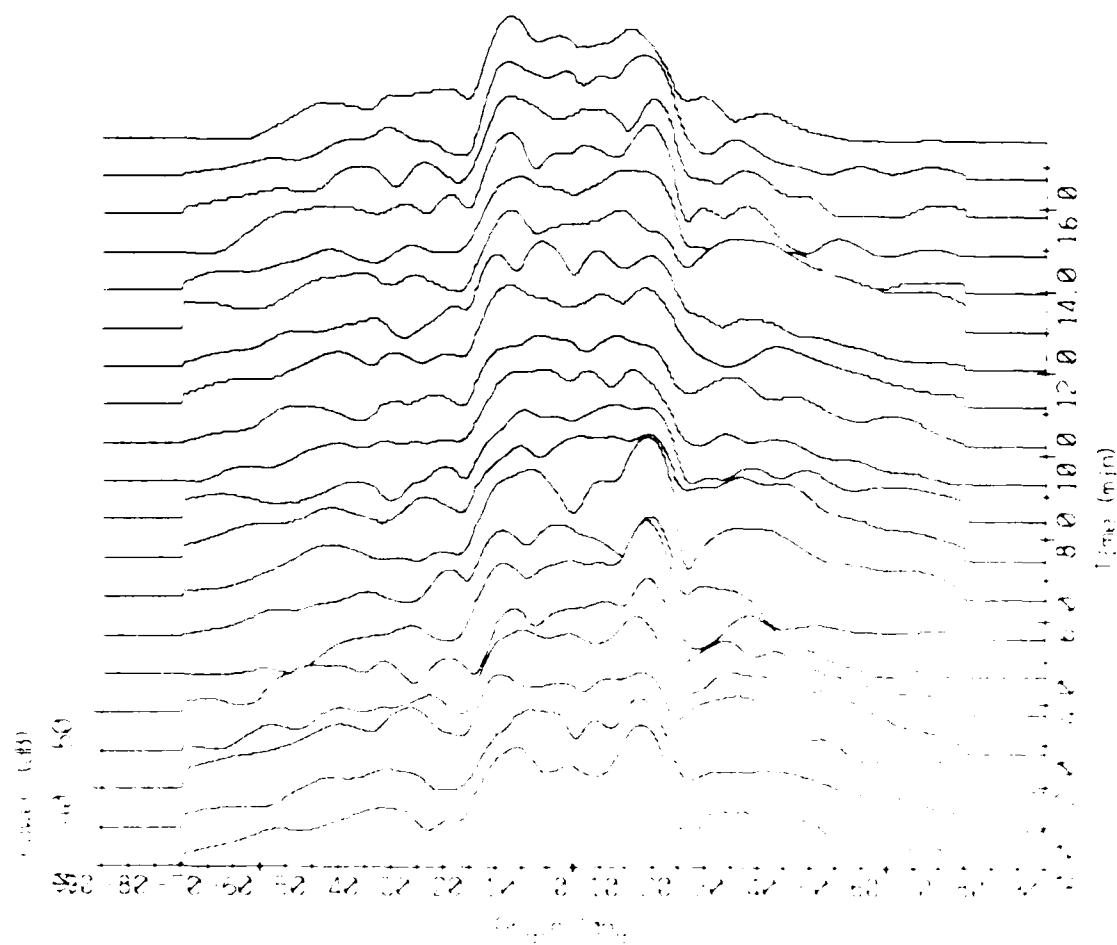
Array Response - 86180 Bin #5316
 $f = 175$ Hz, KB window ($\alpha = 1.5$)



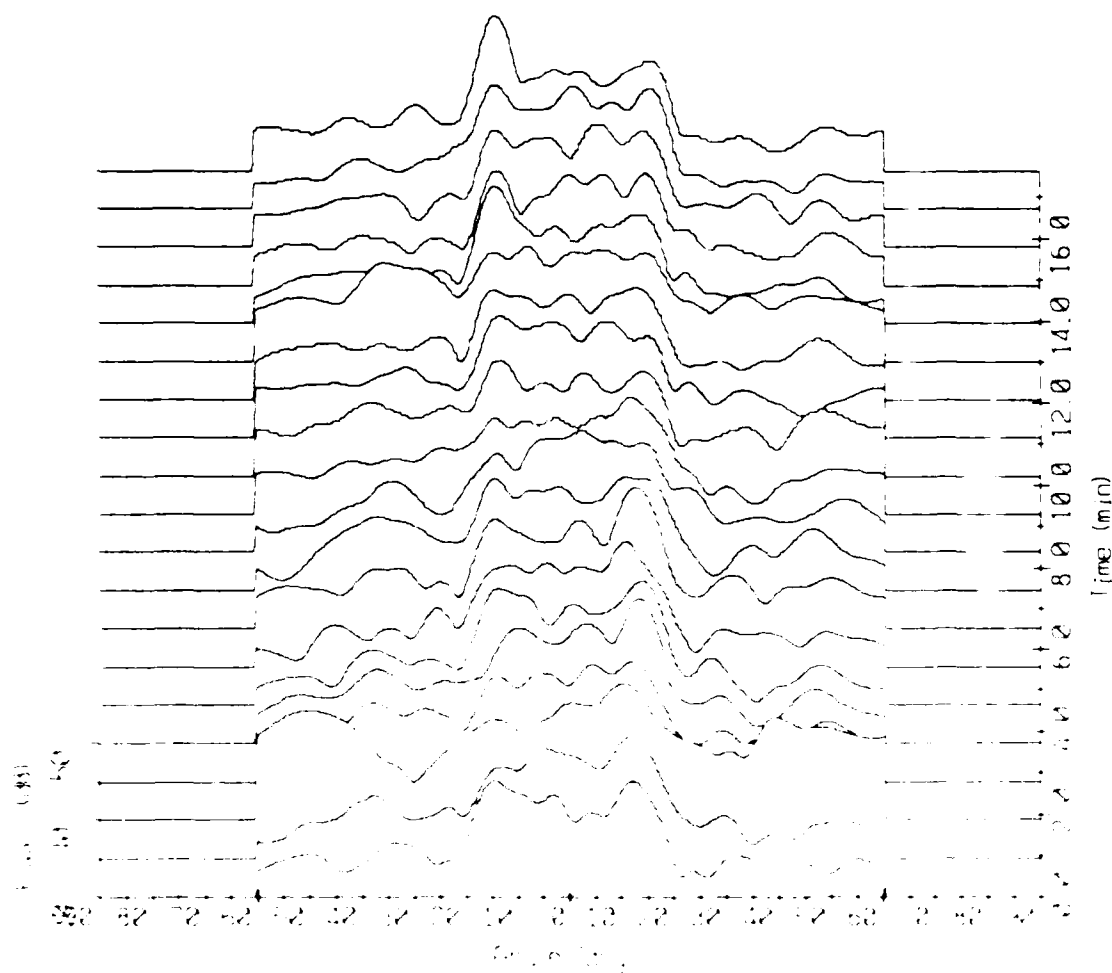
Array Response - 86180 Bin #5490
 $f = 200$ Hz, KB window ($\alpha = 1.5$)



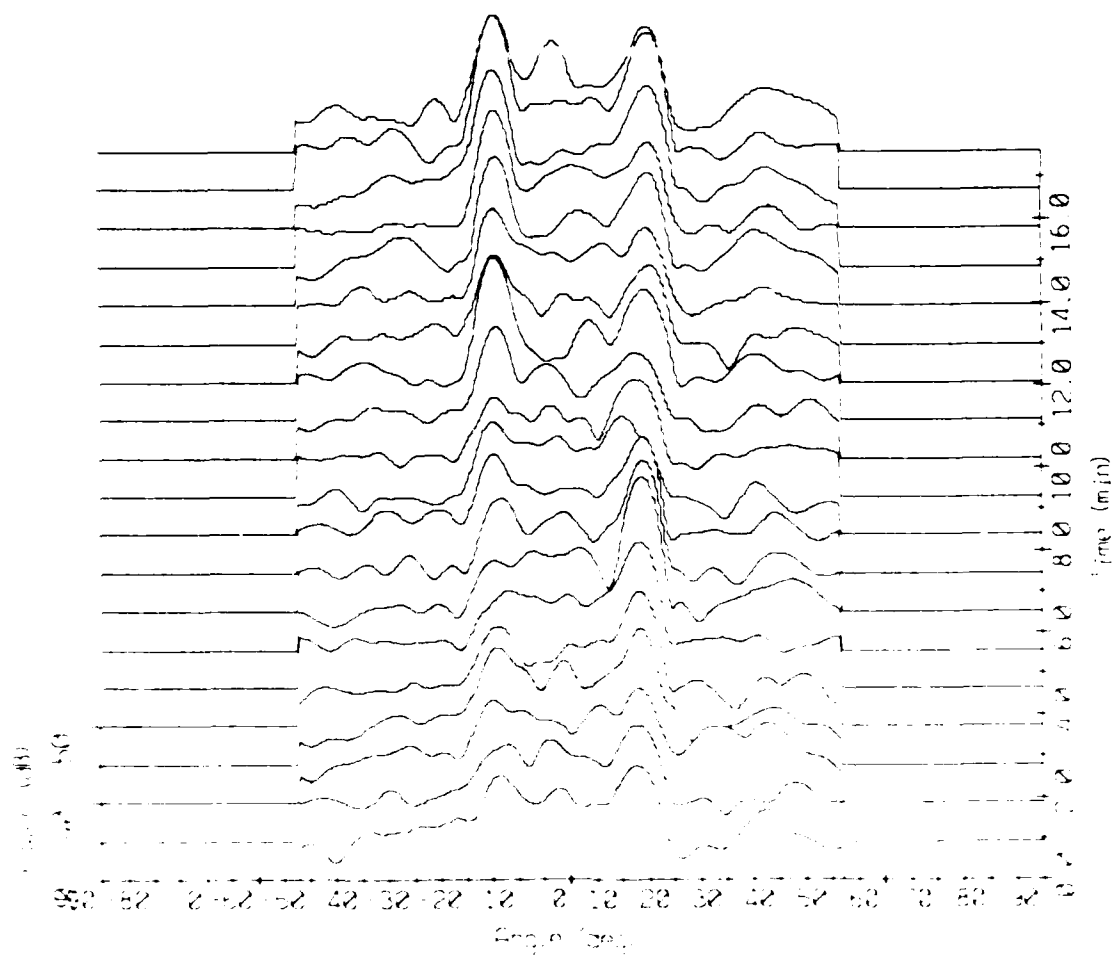
Array Response - 86180 Bin #5664
 $f = 225$ Hz, KB window ($\alpha = 1.5$)



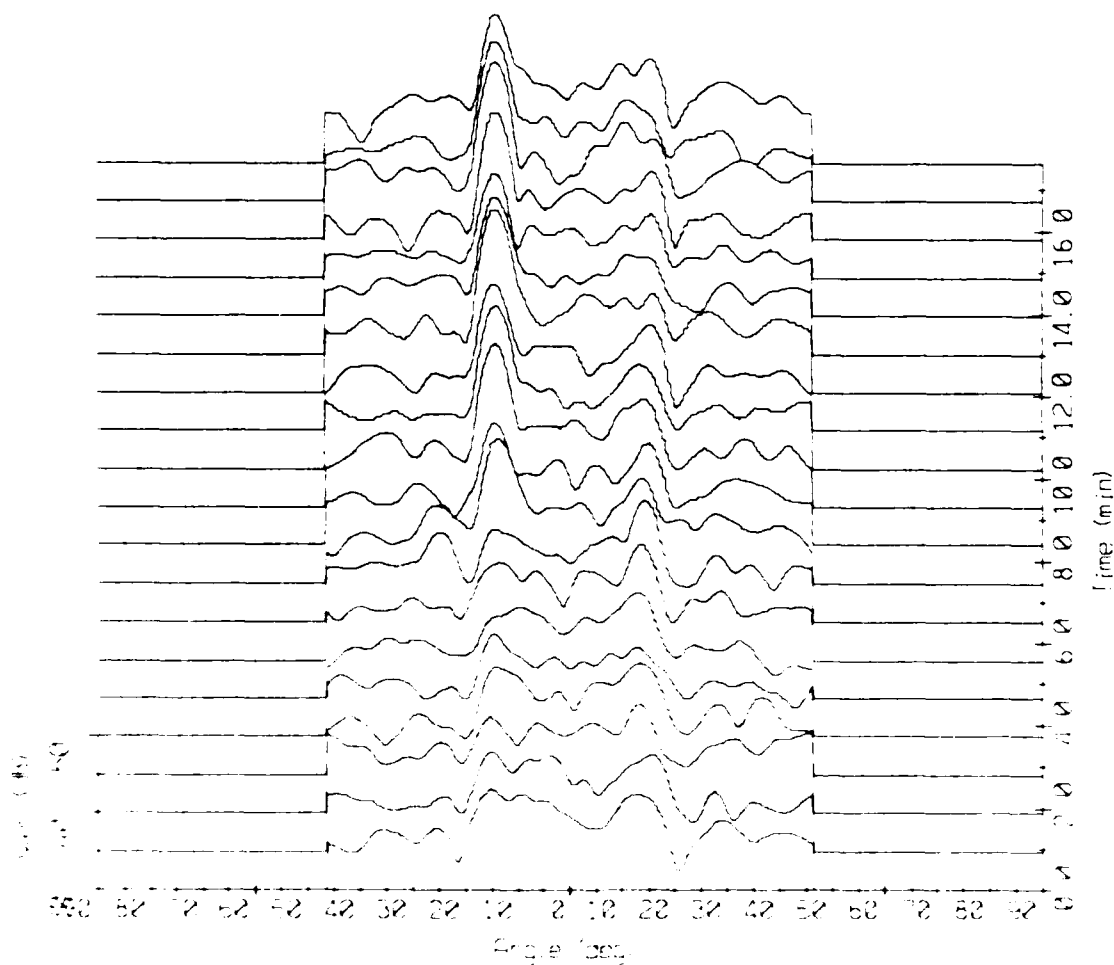
Array Response - 86180 Bin #5832
 $f = 250$ Hz, KB window ($\alpha = 1.5$)



Array Response - 86180 Bin #6012
 $f = 275$ Hz, KB window ($\alpha = 1.5$)

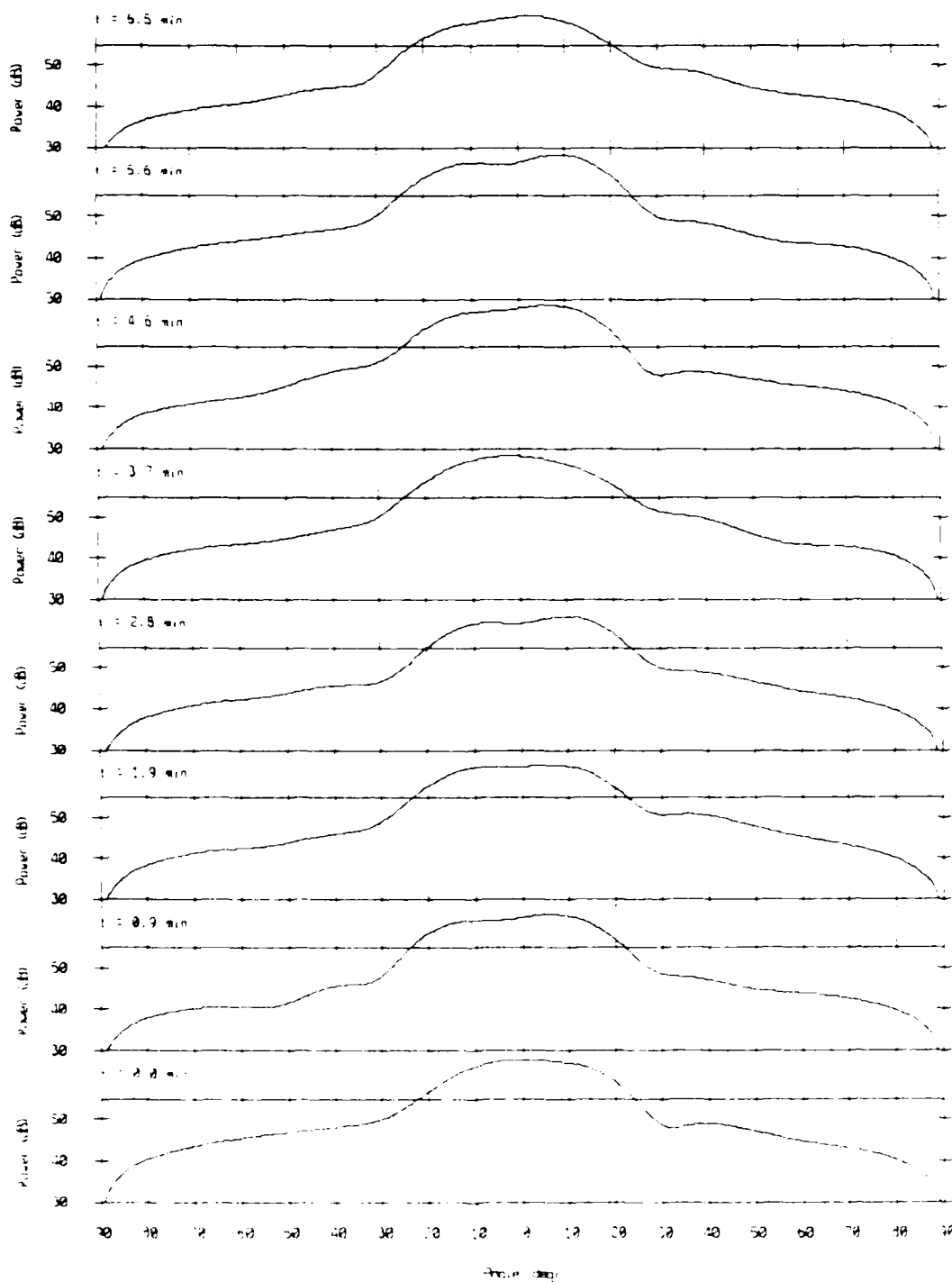


Array Response - 86180 Bin #6186
 $f = 300$ Hz, KB window ($\alpha = 1.5$)



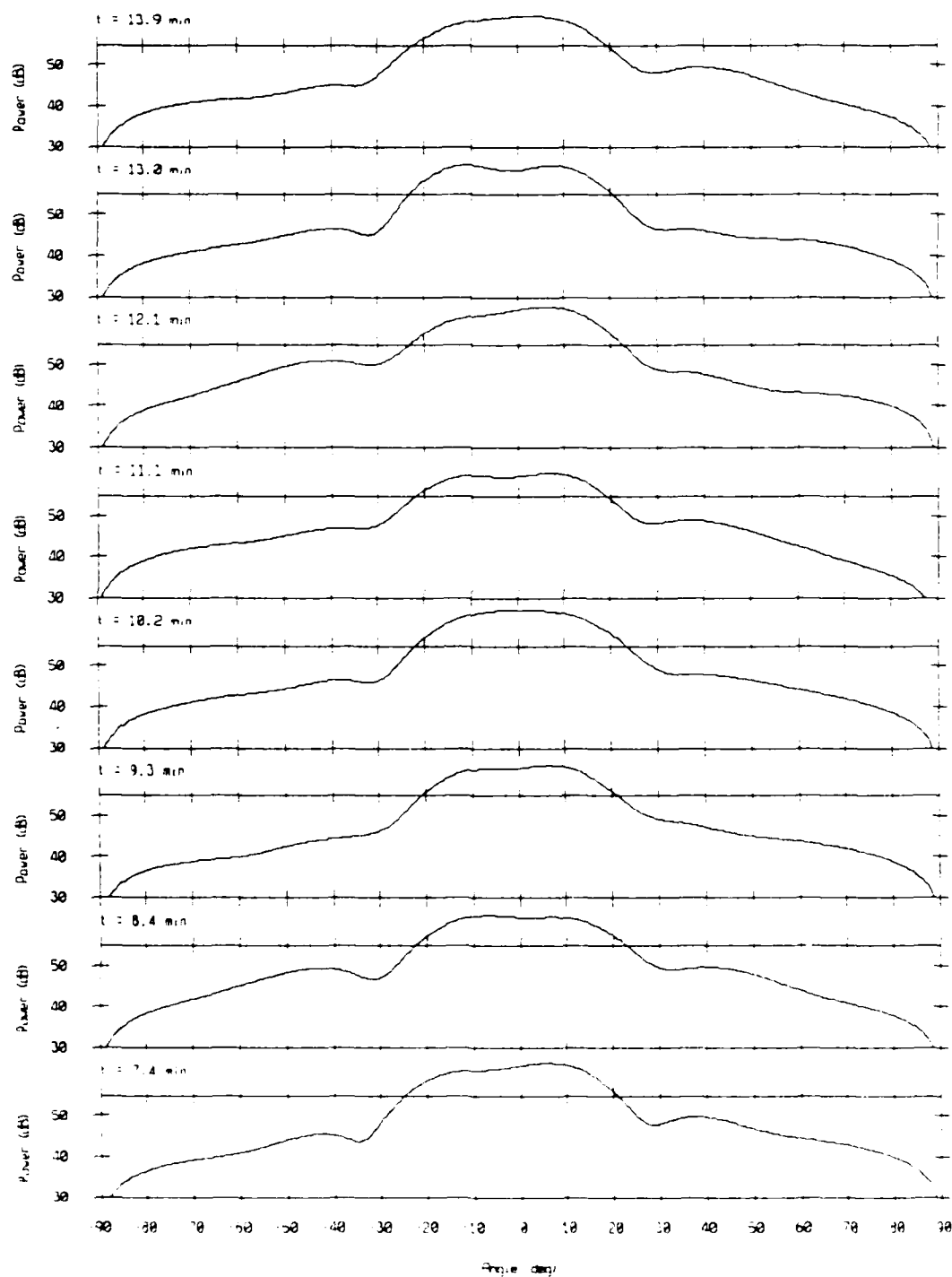
Array Response - 86180 Bin #4619

$f = 75$ Hz, KB window ($\alpha = 1.5$)

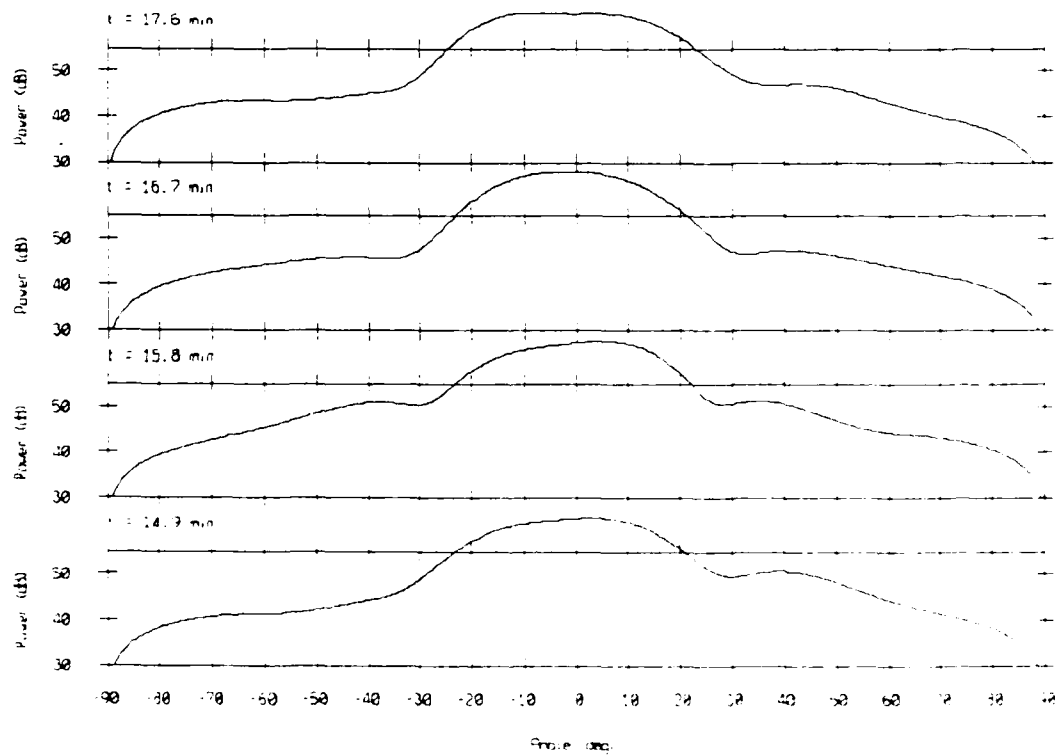


Array Response - 86180 Bin #4619

$f = 75$ Hz, KB window ($\alpha = 1.5$)

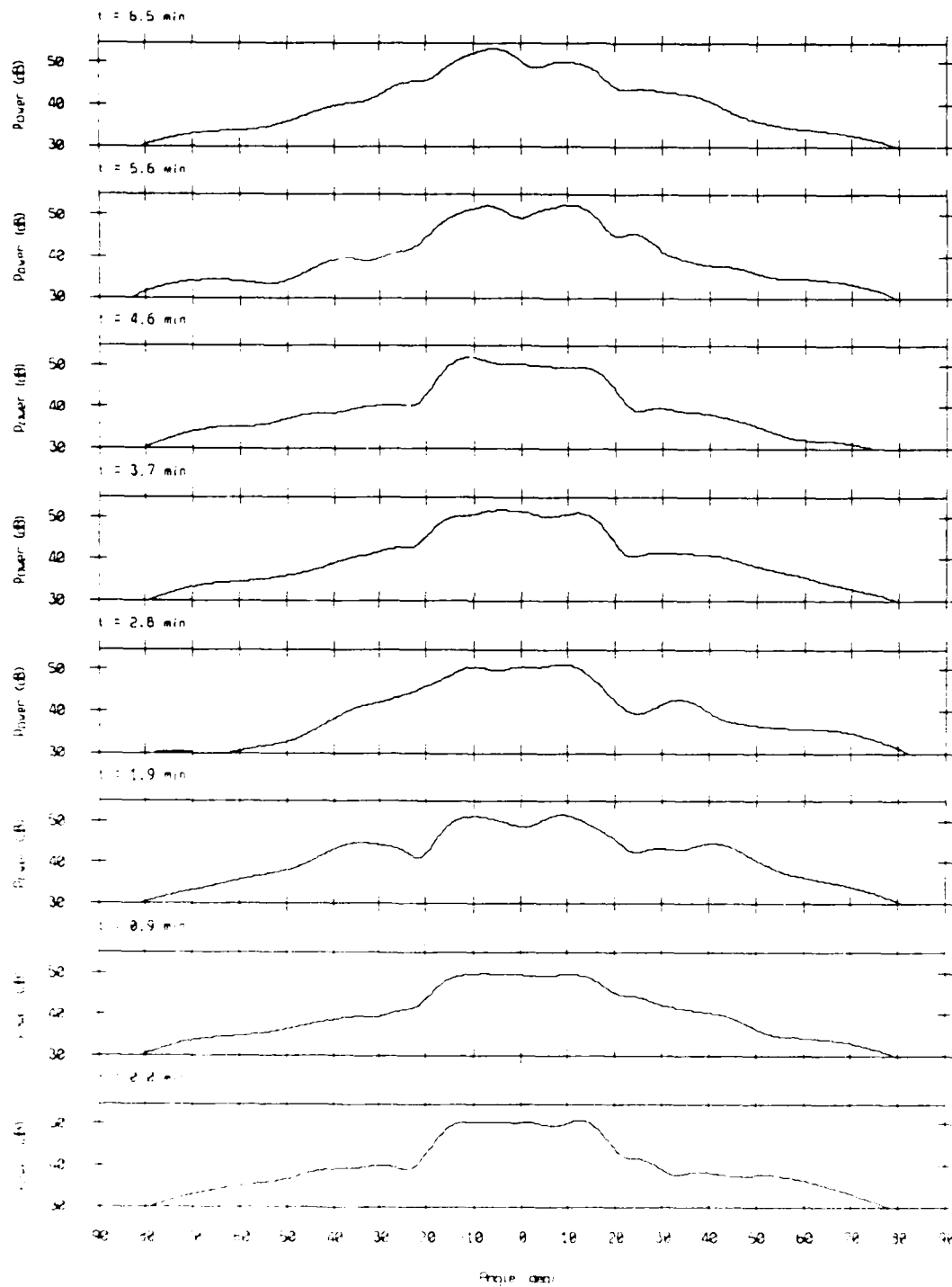


Array Response - 86180 Bin #4619
 $f = 75$ Hz, KB window ($\alpha = 1.5$)



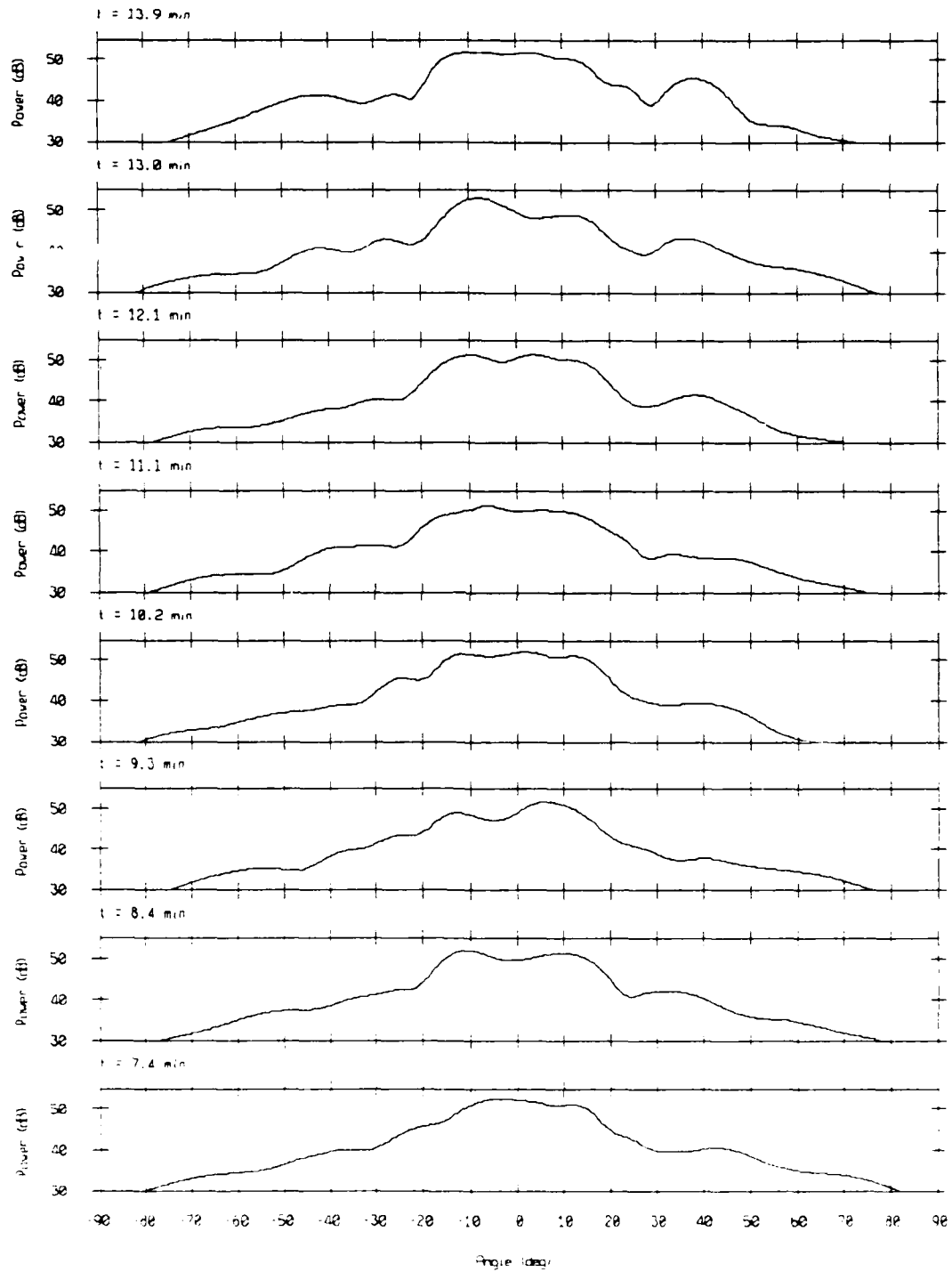
Array Response - 86180 Bin #5141

$f = 150$ Hz, KB window ($\alpha = 1.5$)

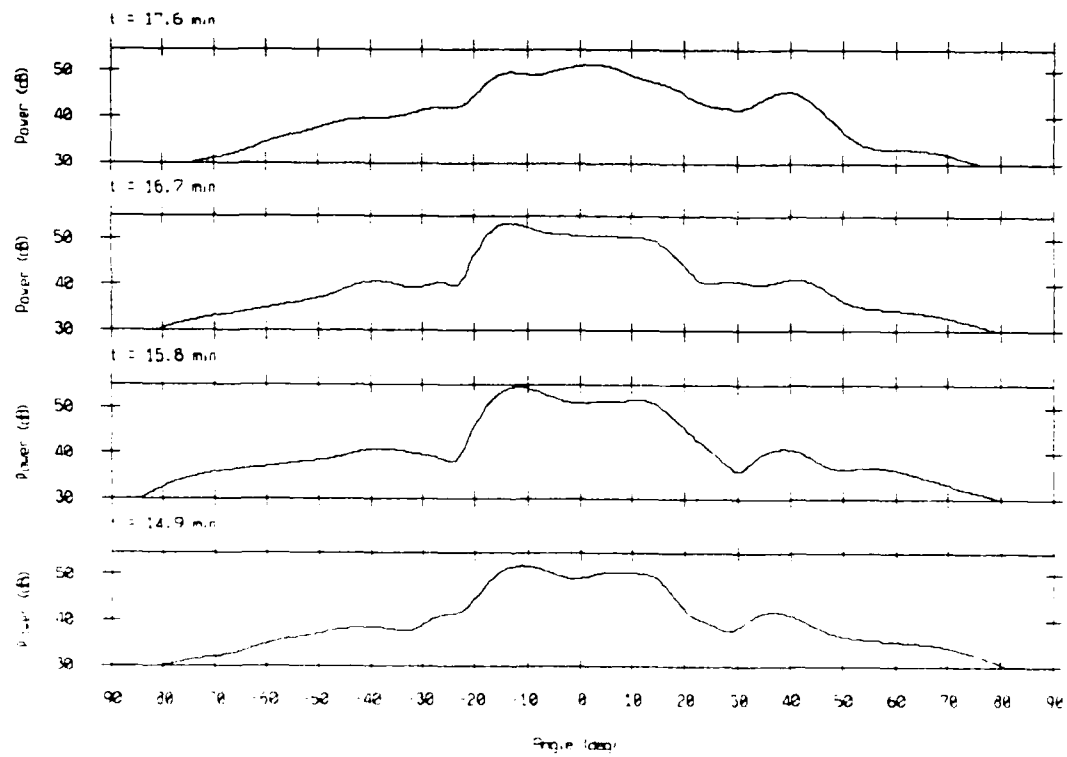


Array Response - 86180 Bin #5141

$f = 150$ Hz, KB window ($\alpha = 1.5$)

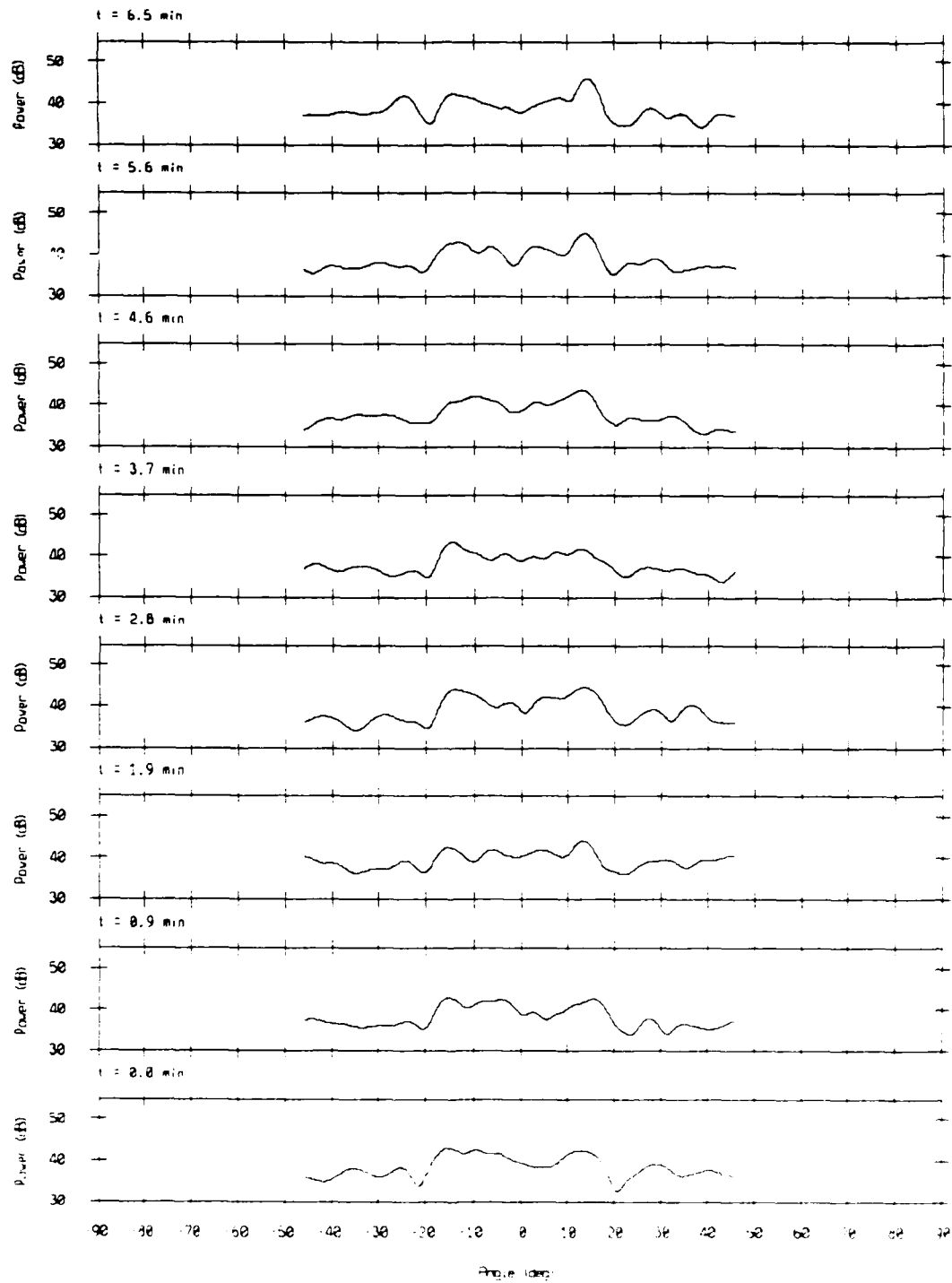


Array Response - 86180 Bin #5141
 $f = 150$ Hz, KB window ($\alpha = 1.5$)



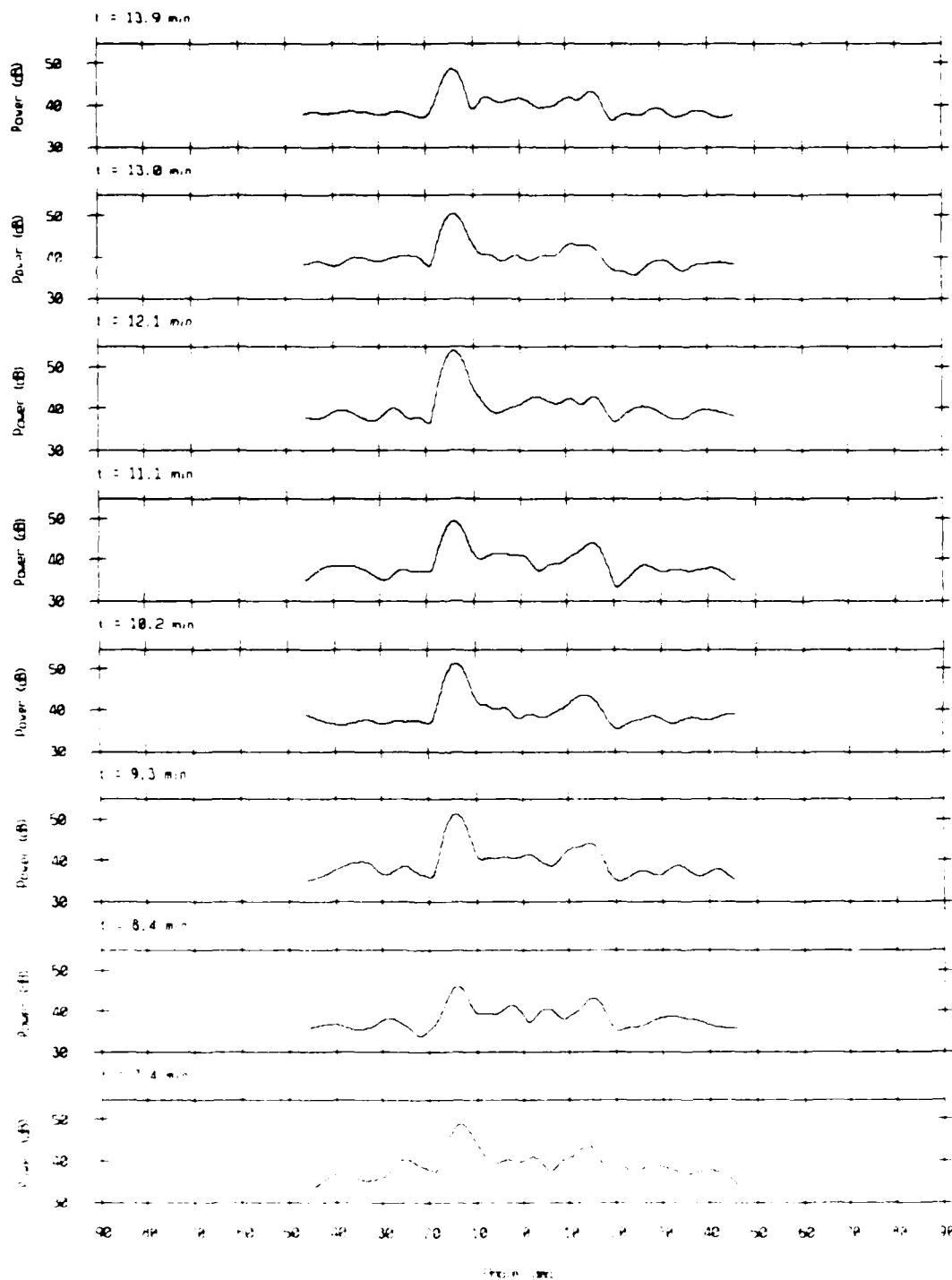
Array Response - 86180 Bin #6186

$f = 300$ Hz, KB window ($\alpha = 1.5$)

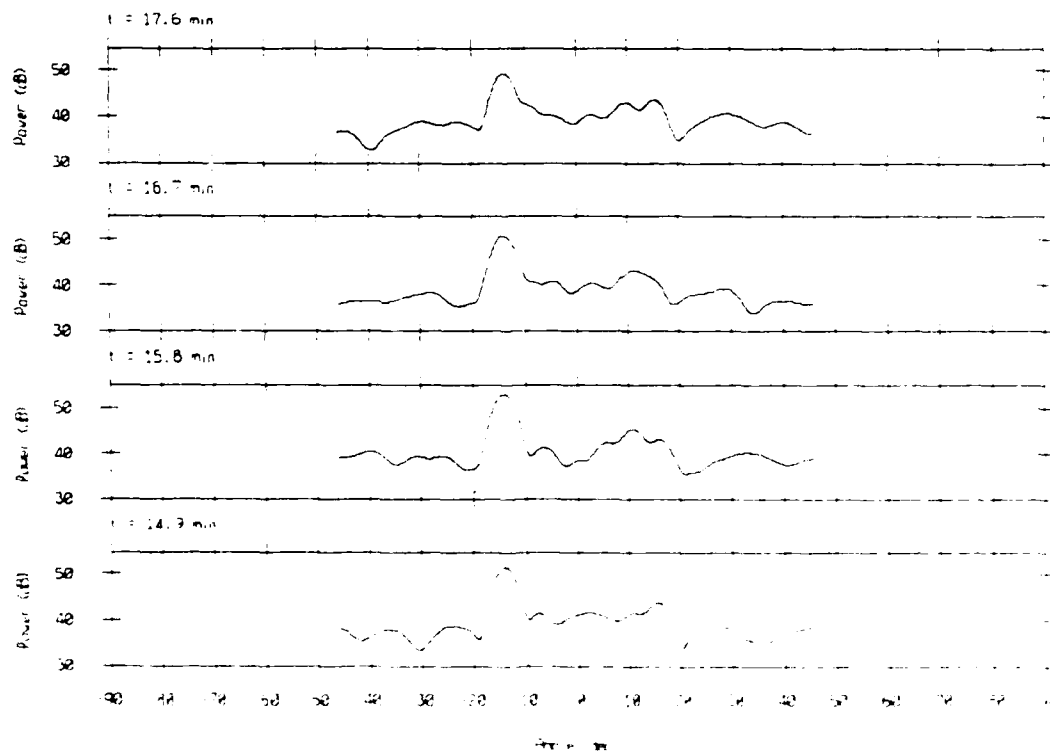


Array Response - 86180 Bin #6186

$f = 300$ Hz, KB window ($\alpha = 1.5$)



Array Response - 86180 Bin #6186
 $f = 300$ Hz, KB window (alpha = 1.5)



END

DATE

FILMED

DTIC

JULY 88